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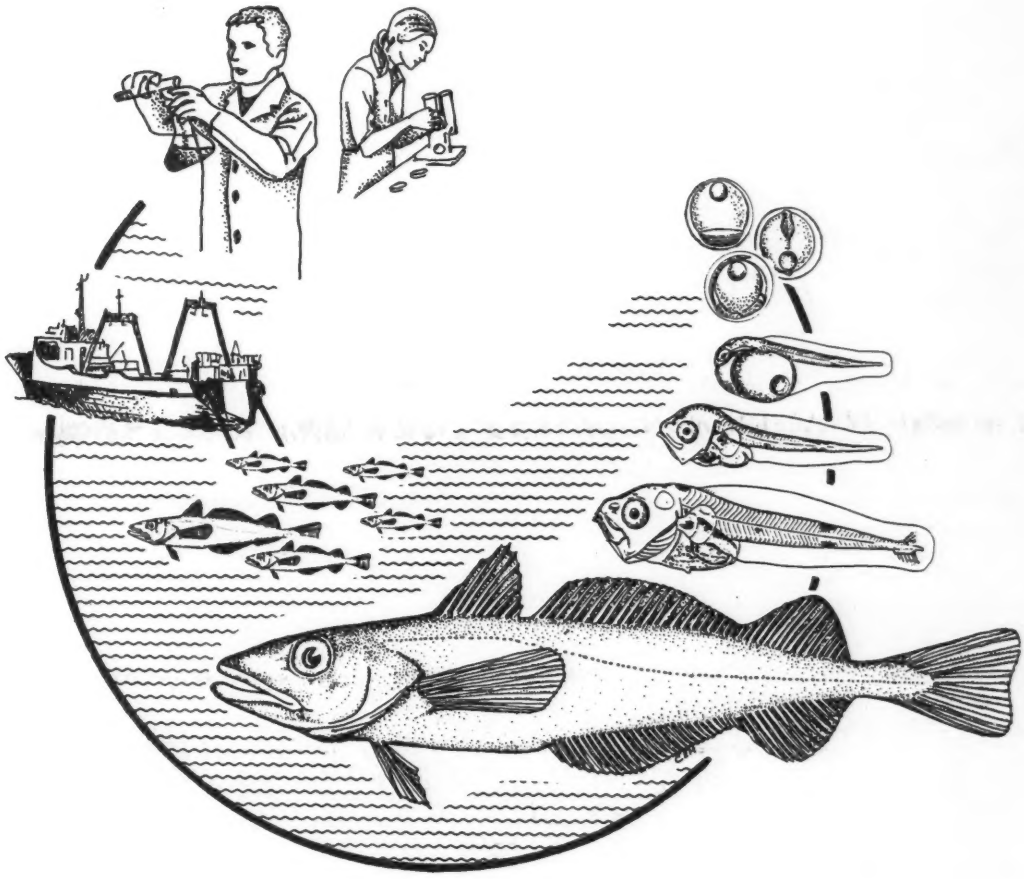
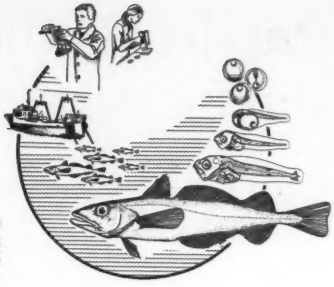


Pacific Whiting

Marine Fisheries REVIEW



The cover illustration for this special section on the Pacific whiting was drawn by Carol Hastings of the NMFS Northwest and Alaska Fisheries Center, Seattle, Wash.

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Pacific Whiting: The Resource, the Industry, and a Management History

A Special Section of the *Marine Fisheries Review*

Introduction

Pacific whiting, *Merluccius productus*, also referred to as North Pacific whiting (Federal Register, 1979) and Pacific hake (Robins et al., 1980), is a codlike species which is a major component of the groundfish community off the coasts of California, Oregon, Washington, and British Columbia. The species is most abundant in coastal waters during the summer when large feeding aggregations occur in depths of 30-300 fathoms. Summer surveys by U.S. and U.S.S.R. researchers have provided biomass estimates ranging from 445,000 to 3,440,000 t.

The fishery 25 years ago was characterized by domestic trawlers delivering relatively small quantities of whiting and other low-valued species to shore plants producing meal and animal foods. It has evolved to become dominated by joint-venture and foreign mothership fleets processing large catches at sea for meal and human consumption. Commercial catches have ranged from about 68,000 to 237,000 t annually since 1967. These fisheries operated under management by state and federal agencies in the past and are now managed by the Pacific Fishery Management Council and Canada Department of Fisheries and Oceans.

Early research centered around the species' biology, behavior, and population size as well as the technical aspects of harvesting. Some of the U.S. work was included in the Circular entitled "Pacific Hake" by the Bureau of Commercial Fisheries (1970). As a fledgling U.S. fleet was employing new technology and bringing Pacific whiting to new meal and fish protein concentrate plants in the mid-1960's, a large Soviet mothership fleet began operating off Washington and Oregon. Catches increased rapidly and the need increased for scientific information on the effects of fishing on the resource.

The demand for resource information, population dynamics studies, processing and preservation research, and management modeling escalated rapidly between 1977 and 1982 as the United States and Canada extended their fishery jurisdictions and developed comprehensive management plans for the Pacific whiting and other groundfishes. The Technical Subcommittee (TSC) of the U.S.-Canada Groundfish Committee convened a meeting of scientists engaged in whiting research in January 1982 to review the state of our knowledge and to consider practical approaches to joint U.S.-Canada fishery management. Recommendations from this group spawned several cooperative studies which included the taxonomy, pathology, and industrial implications of certain whiting parasites; the comparison and refinement of U.S. and Canadian survey methods as a prelude to implementing joint resource assessments; and the development of a model to guide joint management of the resource. The meeting also exposed an array of recent research important to the whiting industry, whiting research, and management.

This compilation of papers in the *Marine Fisheries Review* provides convenient access to information on the Pacific whiting resource and fisheries. These papers review the fisheries, describe Pacific whiting biology, discuss environmental influence on year-class size, examine predator-prey relationships, and summarize harvesting technology. They also examine processing and preservation methods, parasitism and its effects on product quality, the economics of the U.S. industry, and conclude with results of stock assessment surveys and management modeling studies. Primary emphasis is on the offshore whiting stock but overviews of the Puget Sound-Strait of Georgia stocks are included. Some information has been generalized, but the literature cited provides a comprehensive bibliography for the reader seeking further detail. I hope that these papers will help to define the "state of our knowledge" and facilitate the definition of appropriate future studies needed to improve our understanding of species biology and population dynamics. We may thus increase management effectiveness and enhance the economies of harvesting, processing, and marketing this resource.

I wish to thank the authors for their contributions, and the reviewers and all others who gave their time and expertise to these reports are greatly appreciated. Special acknowledgment goes to Roger Pearson and the staff of the Northwest and Alaska Fisheries Center's Publication Program for their attention to editorial detail during the preparation of many of these papers.

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Federal Register. 1979. Common or usual name for nonstandardized food: *Merluccius productus*. Fed. Regist. 44(151):45615-45617.

Robins, C. R., R. M. Bailey, C. E. Bond, J. R. Brooker, E. A. Lachner, R. N. Lea, and W. B. Scott. 1980. A list of common and scientific names of fishes from the United States and Canada. Am. Fish. Soc., Spec. Publ. 12, 174 p.

Thomas A. Dark, *Editor*

Biology and Life History of the Coastal Stock of Pacific Whiting, *Merluccius productus*

GARY D. STAUFFER

Introduction

Research on the life history and biology of the coastal stock of Pacific whiting, *Merluccius productus*, has been conducted since the development of the foreign trawl fishery in the mid-1960's. Insights gained from these studies have been reviewed by Nelson and Larkins (1970) and Bailey et al. (1982). This review provides an updated summary of the information on the biology and life history of the coastal stock of Pacific whiting.

Distribution and Migration

Four major spawning stocks of Pacific whiting have been identified. Of the four, the coastal stock off California, Oregon, Washington, and British Columbia is the most abundant and widely distributed. Other spawning stocks occur in central Puget Sound, the Strait of Georgia, and off the west coast of southern Baja California. The latter stock has been referred to as the dwarf variety by Vrooman and Paloma (1977). The coastal stock is distributed primarily over the continental shelf and slope from central Baja California in the winter (spawning) months to Queen Charlotte Sound during the summer (feeding) period.

The original hypothesis about the annual migration of the coastal stock still holds today. Alverson and Larkins (1969) developed it on the basis of Soviet fishing information, egg and larval distribution, and resource survey data. These authors proposed that after spawning off California and Mexico during the winter, adult whiting move northward to feed during the summer from northern California to Queen Charlotte Sound (Fig. 1).

Subsequent studies have added considerable detail to knowledge about the distribution and migration of coastal whiting. Ermakov (1974), for example, noted that the largest individuals tend to make the longest northerly migrations. Similarly, Dark

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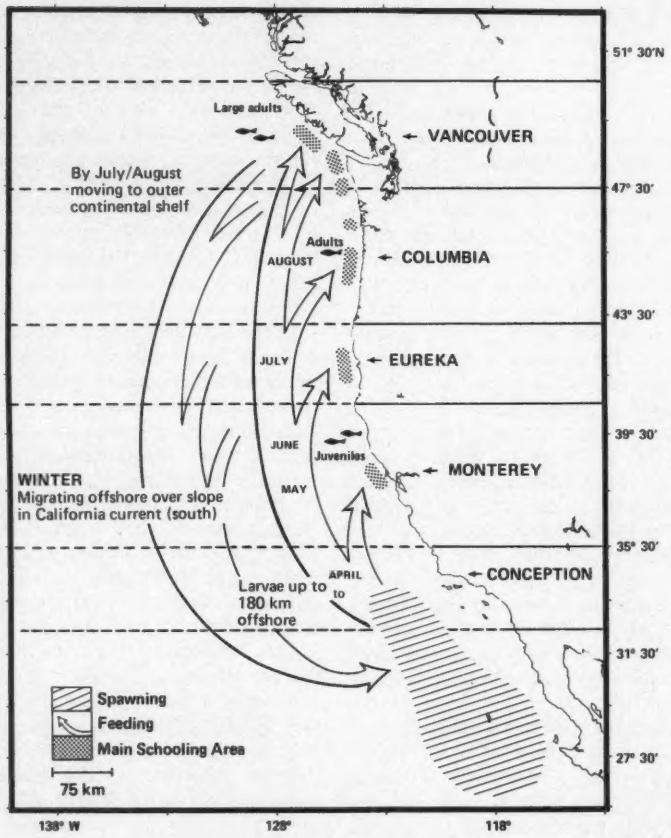

Figure 1.—Migratory patterns of Pacific whiting (from Bailey et al., 1982).

et al. (1980) reported that juvenile whiting are concentrated mainly off central California and southward.

Ermakov (1974) also commented on the intraseasonal movement of the adult fish. Using data collected from the Soviet fishing fleet during 1965-69 and from associated research cruises, he reported that large, spawned-out individuals of the type observed off San Francisco in early March gradually began to appear in an area 111.2 km (60 n.mi.) north within a few weeks. By the third week in April, large whiting were showing up off Oregon and Washington. The largest individuals usually arrived first and were followed by the smaller ones. Schools of large whiting first appeared off Vancouver Island in late May. The lead schools migrated at a rate of 5.5-11.1 km (3-6 n.mi.) per day. With respect to the inshore-offshore distribution of adult whiting, Ermakov reported that during the spring, schools off Oregon, Washington, and California are generally found over the continental slope but not over the shelf. In June they begin to move shoreward over the shelf to depths of 90 m (50 fathoms) or less. Few remain over the slope during July or early August until the schools begin their return (spawning) migration by moving westerly over the slope and eventually southward by early September. Most have departed by fall. Bailey et al. (1982) add that the southward migration may be triggered by the shift of the wind direction in the fall and the appearance of the Davidson Current.

Beamish and McFarlane (1985) report that the migration of whiting in and out of the Vancouver area is quite variable. In general, large quantities are present from mid-June until October, although fishable concentrations have been reported there as early as April and as late as November. They also note that males arrive off Canada later than females and depart earlier.

Whiting undertake strong diurnal migrations while on the feeding grounds, apparently in response to the vertical migrations of euphausiids, their primary food. During the day the schools are densely concentrated between 100 and 250 m. Daytime schools are composed of fish of similar size that move slowly in random directions. At sunset the schools begin to disperse and rise toward the surface. At night (2200-0300 h) they are scattered from near the surface to 20 m, moving quickly toward the bottom at dawn. Diurnal migration diminishes as fall approaches (Ermakov, 1974). Dark et al. (1980) report that there is no relation between fish size and school depth during the feeding season.

Reproduction

Information on the spawning biology of coastal whiting is limited because of the difficulty of locating adult schools in the spawning areas. Unlike the dense layers of spawning adults found in the Strait of Georgia stock (Thompson and McFarlane, 1982), spawning schools of coastal whiting are apparently dispersed over a wide area of the continental slope from central California to northern Baja California.

The few observations that have been made were reviewed by Bailey et al. (1982). Erich et al. (1980) and Stepanenko[1,2] reported spawning schools out to 400 km off California. During the 1979 U.S.-U.S.S.R. cooperative ichthyoplankton survey of the California Current system, Stephanenko found two dense spawning schools of whiting 220-330 km (120-160 n.mi.) off central California at lat. 35°45'N. These schools were in a dense layer at 100-200 m and extended for 7.8 km (4.2 n.mi.). One was found in the evening and the other at midnight—both in early February. In 1980, three groups of dense spawning schools were found at 340-400 m. These were spotted between 1300 and 2100 h in late February, 220-370 km (120-200 n.mi) offshore at lat. 31°00'N. The schools were from 1.6 to 16 km long.

Generally, what knowledge there is about the spawning of Pacific whiting has been deduced from the California Cooperative Oceanic and Fisheries Investigations (CalCOFI) egg and larval surveys. These surveys show that whiting larvae are abundant from December through April within 400 km of the coast from central California to northern Baja California. Bailey et al. (1982) used the peak occurrences of whiting eggs and small larvae to pinpoint January and February as the peak spawning months. They found the majority of eggs and small larvae (2-3 mm) off central California over the areas of the continental slope with bottom depths ranging from 130 to 500 m. Off southern California, with its many eddy currents and varied bottom topography (alternating deep basins and islands or banks) eggs and larvae are distributed out to 400 km from shore. Whiting eggs and small larvae (<8 mm) appear to aggregate at the 40-100 m depth interval near the base of the thermocline or mixed layer (Ahlstrom, 1959; Bailey, 1982). Because spawning occurs at depths of 130-500 m, it must be assumed that eggs ascend in the water column to a level of neutral buoyancy.

Female whiting in the coastal stock mature at 40 cm (16 inches) or more and at weights greater than 0.4 kg (0.9 pounds) (Best, 1963; Dark, 1975). These minimum sizes are achieved by some 3-year-old fish and most 4-year olds. MacGregor (1971), on the other hand, did find mature females as small as 12.5 cm and 22.2 cm off southern and central Baja California, respectively. It is likely, however, that the smaller fish in these samples were from the so-called "dwarf" stock rather than from the coastal stock.

Because of the scarcity of the samples and the variability of the

[1]Stepanenko, M. A. 1980. Reproductive condition and assessment of the spawning stocks of Pacific hake, California anchovy, horse mackerel (and some other fish species in the California Current Zone in 1979). Unpubl. manuscr. Pacific Scientific Research Institute of Fisheries and Oceanography (TINRO), Vladivostok, U.S.S.R.

[2]Stepanenko, M. A. 1981. Assessment of stocks and reproduction conditions of some commercial fish off the Pacific Coast of North America in 1980. Unpub. manuscr. Pacific Scientific Research Institute of Fisheries and Oceanography (TINRO), Vladivostok, U.S.S.R.

Table 1.—Values of growth parameters for whiting estimated by Dark (1975) and Francis (1983) for the von Bertalanffy growth model and the length-weight relationship for length measured in cm and weight in kg.

Analysis and growth parameter	Dark (1975)			Francis (1983)
	Male	Female	Male & Female	Male & Female
von Bertalanffy				
l (cm)	56.29	61.23	60.85	55.40
k	0.30	0.30	0.30	0.26
t_o	0.20	0.01	0.03	1.61
Length-weight relationship				
a	0.00003468	0.00002044		0.00001815
b	2.55618	2.69509		2.73343

Table 2.—Average length and weight of female and male Pacific whiting from the offshore stock for ages 1.0-13.3 years derived for growth equations given by Dark (1975).

	Females				Males			
	Average fork length		Average weight		Average fork length		Average weight	
Age	in	cm	lb	kg	in	cm	lb	kg
1.0	6.1	15.4	0.07	0.032	6.1	15.4	0.08	0.038
2.0	11.0	28.0	0.36	0.163	10.6	26.9	0.35	0.157
3.3	16.2	41.2	1.01	0.460	16.6	42.2	1.09	0.496
4.3	18.2	46.2	1.38	0.626	17.6	44.6	1.26	0.570
5.3	19.0	48.2	1.55	0.704	18.7	47.6	1.49	0.675
6.3	19.8	50.3	1.73	0.786	19.6	49.7	1.65	0.751
7.3	20.4	51.8	1.88	0.854	20.0	50.9	1.76	0.798
8.3	21.4	54.3	2.13	0.967	20.6	52.3	1.89	0.857
9.3	22.4	57.0	2.43	1.102	21.6	54.8	2.12	0.964
10.3	23.2	58.9	2.66	1.207	22.2	56.4	2.29	1.041
11.3	23.2	59.0	2.67	1.211	22.0	55.9	2.24	1.015
12.3	24.0	60.9	2.91	1.320				
13.3	24.3	61.8	3.03	1.374				

observations, the fecundity of coastal whiting is not well defined. MacGregor (1966) and MacGregor (1971) examined 50 females collected off Baja California. For females collected off northern Baja California (and presumably of the coastal stock), he found that mature ovaries contained from 83 to 556 eggs in the advanced stage of development per gram of body weight (average 197 eggs per gram of body weight). The data were too limited, however, to predict rates of change in the number of eggs per unit weight for the larger females, although this information is available for the Strait of Georgia stock[3]. According to MacGregor (1966), and MacFarlane and Beamish (1985), Pacific whiting spawn only once per season.

Growth

Growth of Pacific whiting has been studied on the basis of changes in the average length and weight at age, with age having been determined from ring counts on the fish's otoliths. This method has been found by Dark (1975), Beamish (1979), and Beamish (1981) to be reasonably accurate through the first 11 years of life—the period when the bulk of the growth accrues.

The standard von Bertalanffy growth model and length-weight relationship have been presented by Dark (1975) and Francis (1983) as follows:

$$l_t = L_\infty (1 - e^{-k(t - t_o)}), \text{ and}$$

$$w = al^b$$

where

l_t and w = body length at age (t) and body weight;

L_∞, k, and t_o = the von Bertalanffy parameters for maximum length, growth rate, and age at zero length; and

a and b = regression coefficients for length-weight relationship.

Estimates of the growth parameters given by Dark (1975) and Francis (1983) are summarized in Table 1. In general, the relationships derived by both authors coincide for the major group of fish and diverge only at the extremes of the age and length ranges. Average length, in inches and centimeters, and average weight, in pounds and kilograms, estimated by parameter values given by Dark (1975) are listed in Table 2 for fish between 1.0 and 13.3 years of age.

The growth pattern described by Dark (1975) showed that whiting reach about 70-75 percent of their maximum length and about 50 percent of their maximum weight by 4.3 years (the age at which whiting begin to mature sexually). He also found that mature females were about 1 inch (2.5 cm) longer than males of the same age. The differential growth between males and females was not apparent before 4.3 years. Considered in conjunction with the longer migrations of larger fish, the larger size of mature females would tend to explain the preponderance of females in the northern areas of the summer feeding grounds described by Beamish and McFarlane (1985). Average maximum sizes reported by Dark (1975) are about 56 cm (22 inches) and 1 kg (2¼ pounds) for males and 61 cm (24 inches) and 1⅓ kg (3 pounds) for females. Females have been observed up to 81 cm (32 inches) and 2¼ kg (5 pounds). Length at age is variable between year classes. Dark found the slowest growth rate for the large 1961 year class, which suggests density-dependent growth.

Francis (1983) examined within-year growth in terms of both length and weight and found both to be seasonal, with fish growing during the summer feeding season and then ceasing to grow (actually losing 5-10 percent of their weight) during the winter spawning period. Weight loss can be attributed to energy expended in the migratory and reproductive processes. The seasonal growth pattern reported by Francis for coastal whiting is similar to that observed in the Strait of Georgia stock (McFarlane and Beamish, 1985).

Mortality

Estimates of annual instantaneous

[3]G. A. McFarlane, Pacific Biological Station, Nanaimo, B.C., V9R 5K6, Canada. Pers. commun., 1982.

Table 3.—Estimates of annual instantaneous mortality rates of Pacific whiting (from Bailey et al., 1982).

Investigators	Males	Females	Both sexes
M: Natural mortality			
Tillman (1968)	0.72	0.62	$\bar{x}$ = 0.67
Nelson and Larkins (1970)			0.56
Efimov (1974)[1]			0.35
PFMC[2]			0.30-0.60
Jackowski (1980)[3]			0.30
Erich et al. (1980)			0.56
Low (1978)[4]			0.50
Francis (1983)			0.19-0.86 (variable age-specific natural mortality
F: Fishing mortality			
Efimov (1974)[1]			0.30
Erich et al. (1980)			0.67
Z: Total mortality			
Efimov (1974)[1]			0.65
Erich et al. (1980)			1.23

[1]Efimov, Y. N. 1974. The size of stocks and status of fishery of Pacific whiting. Unpubl. manuscr. Pacific Scientific Research Institute of Marine Fisheries and Oceanography (TINRO), Vladivostok, U.S.S.R.

[2]Pacific Fishery Management Council. 1980. Pacific coast groundfish plan. Draft rep. Pacific Fishery Management Council, 526 S.W. Mill St., Portland, OR 97201.

[3]Jackowski, E. 1980. Biological characteristics of Pacific whiting from Polish surveys of the west coast of the U.S.A. and Canada in 1979. Unpubl. manuscr. presented at the U.S.-Poland bilateral meetings, 1980.

[4]Low, L. L. 1978. Hake natural mortality and yield potential. Unpubl. manuscr. Northwest and Alaska Fisheries Center, NMFS, NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112.

rates of natural mortality (M) have been derived by a number of authors (Table 3). Two factors tend to introduce variability to the estimates. First is the differential rate of migration, hence the segregation of the various size groups during the summer. This makes it difficult to obtain representative samples of the overall population. Second is the wide fluctuation in annual recruitment. Nonetheless, most values of (M) fall between 0.30 and 0.67, implying that between 26 and 49 percent of adult whiting would die each year of natural causes if there were no fishing. Although an intermediate value (M = 0.45) constant throughout the life span is frequently used in population models for Pacific whiting, Francis (1983) considered it probable that factors such as spawning stress make it likely that natural mortality increases with age. He assumed, therefore, that natural mortality increases 10 percent with each additional year of age and proceeded to compute age-specific values of (M) ranging from 0.19 for age 3 fish to 0.86 for age 11 fish.

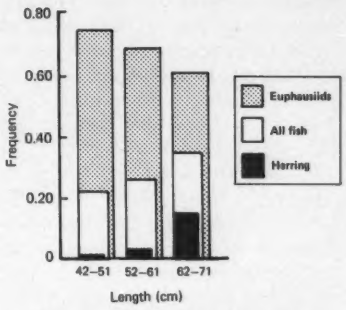

Figure 2.—Frequency of occurrence of prey types in different Pacific whiting size classes off Vancouver Island (data from Outram and Haegel, 1972; figure from Bailey et al., 1982).

Feeding Behavior

Several authors have contributed information on the feeding behavior of Pacific whiting. Livingston and Bailey (1985) have reviewed the role of the species both as a predator and as a prey item throughout its life history. As juveniles and adults, whiting feed on euphausiids, fish, shrimp, and squid during the spring, summer, and fall. Apparently, mature individuals do not feed during the spawning season (Tillman, 1968). Alton and Nelson (1970) reported that during the growth season, whiting feed at night near the surface. From stomach samples collected over a 15-h period beginning in the early evening, Livingston (1983) found stomachs fullest at 1800 h (the first hour of sampling). With the exception of a minor peak at 0300 h, stomach fullness generally decreased after 1800 h until it increased again at 0900 h, the last hour of sampling. The peaks at 1800 h, 0300 h, and 0900 h coincided, it was noted, with the times during which whiting and euphausiids occur together in the water column in the greatest concentrations—near bottom in the evening and morning and near the surface after midnight. The daily ration of adult whiting has been estimated to be 0.71-1.09 percent body weight/day by Francis (1983) and as high as 2.5 percent by Livingston (1983).

The species composition of the diet varies with size, age, and geographic location. Generally, euphausiids make up 80-90 percent of the food items but decrease in importance for larger fish on their northward migration (Fig. 2). Fish make up an increasing percentage of the food as the whiting grow larger. When schools of adult and juvenile whiting occur together off northern California in the summer, adults may feed on the juveniles (Bailey et al., 1982). Other fish that are important food items for whiting are Pacific sand lance, *Ammodytes hexapterus*; Pacific herring, *Clupea harengus pallasi*; and deep-sea smelt, *Bathylagus* spp. (Outram and Haegele, 1972). Gotshall (1969) found that shrimp made up 50-60 percent of the stomach contents of samples taken off northern California in spring and summer. Other studies, however, have not revealed shrimp to be as important in the diet.

Recruitment

Young whiting are recruited to the exploitable stock at ages 3-6, beginning with age 3 fish off northern California. Recruitment to the summer fishery off Oregon and Washington is nearly complete for 5-year-olds. Beamish and McFarlane (1985) found that recruitment to the fisheries off Vancouver occurred at ages 5 and 6. Since the development of the whiting fishery, the harvest has been dominated by a number of large year classes. Dark (1975), Bailey (1981), Francis and Hollowed (1985), and Beamish and McFarlane (1985) report that the 1961, 1970, 1977, and 1980 year classes were strong and that the 1960, 1967, and 1973 year classes were moderately strong.

The biological and environmental factors influencing the recruitment of whiting, first described by Bailey (1981), are considered in detail by Bailey and Francis (1985). Bailey found that the years producing strong year classes were correlated with the

presence of strong onshore ocean currents. These conditions are associated with weak upwelling and warm coastal sea-surface temperatures. He reasoned that poor recruitment resulted from a low rate of survival of the larvae which had been transported offshore by coastal upwelling currents which, in turn, were created by north winds blowing along the shore.

Abundance

The primary method for measuring the abundance of the coastal whiting stock has been by trawl-acoustical surveys off the continental slope and shelf from central California to Vancouver Island. Surveys by the Northwest and Alaska Fisheries Center produced biomass estimates of 445,000 metric tons (t), 1,129,000 t, and 1,537,000 t for the years 1975, 1977, and 1980, respectively (Bailey et al., 1982; Nelson and Dark, 1985). The large increase in 1980 was attributed to the high abundance of juveniles from the strong 1977 year class that was found off central California.

Similar surveys have been conducted by Soviet researchers since 1967. The results of these surveys, which appear in unpublished manuscripts submitted at the annual U.S.-U.S.S.R. bilateral meetings, were summarized by Bailey et al. (1982). Soviet estimates of biomass averaged 1,360,000 t for 1967-73, and were 1,400,000 t and 1,860,000 t for 1974 and 1975, respectively. The Soviets made two surveys in 1978. Biomass estimates were 770,000 t on the basis of the early summer survey and 1,470,000 t for the late summer survey. Similarly, the 1979 estimates were 2,870,000 t and 1,200,000 t based on their July-August and August-September surveys, respectively. These large intra-annual differences more likely reflect differences in the distribution and availability of the fish along the coast, differences in the areas surveyed, and variations in the effectiveness of the echo sounding equipment rather than actual changes in the stock biomass.

Francis (1983) estimated the biomass of the coastal whiting stock for 1973-80 using age composition data from the commercial fishery in a cohort analysis. Allowing for varying regimes of seasonal growth and natural mortality, his biomass estimates for fish age 3-11 averaged 1,253,000 t annually. Biomass peaked at 1,450,000 t in 1976 and again in 1980 as a result of the recruitment of 3-year-olds from the strong year classes of 1973 and 1977.

Another source of biomass estimates is the series of CalCOFI surveys to assess the pelagic spawning products of fish populations within the California Current region since 1951. The Pacific whiting has been one of the dominant species sampled in these surveys. For the past decade, cooperative surveys between the United States and the Soviet Union have been directed specifically at measuring the abundance of whiting larvae during the months of peak spawning.

Ahlstrom (1968) was the first to derive estimates of the biomass of the coastal whiting stock. Using the relative abundance of whiting and jack mackerel, *Trachurus symmetricus*, larvae as a basis, he estimated the biomass of coastal whiting at 1,800,000-3,600,000 t. In more recent years Soviet scientists have used information obtained on the cooperative U.S.-U.S.S.R. ichthyoplankton surveys to develop biomass estimates for presentation at the annual bilateral meetings[1,2,4,5]. These estimates are generally about double those based on trawl-acoustic surveys, but are similar to the estimates obtained by Francis (1983) where he assumed a constant natural mortality rate.

Bailey et al. (1982) asserts that estimates of the spawning biomass of whiting derived from egg and larval surveys are likely to be biased and imprecise because 1) fecundity estimates are weakly based, 2) the mortality rate of eggs and larvae is poorly defined, and 3) the number of stations surveyed during the spawning season is relatively small considering the extremely patchy distribution of the eggs and larvae in the ocean.

These limitations notwithstanding, the surveys have provided two indices of the biomass of spawning whiting. First is the density of larvae within the survey area expressed as number of larvae/10 m^2 of sea surface area. This index is taken to be indicative of the density of the spawning biomass. Second is the percentage of the occupied stations that contain whiting larvae. This measures the expanse of the spawning area. Both indices can be influenced by the timing of the surveys and the geographic areas covered. Timing has varied over the years, but generally the surveys have covered a 30-day period between mid-January and 1 March. For the first 25 years of the CalCOFI surveys, stations were sampled from San Francisco (lat. 38°N) to central Baja California (lat. 25°N). In recent years the majority of these surveys of whiting larvae have been restricted to the regions north of San Diego (lat. 32°N).

The indices of abundance derived from the larvae surveys (Table 4) can be used to evaluate the status of the coastal stock of Pacific whiting from 1951 to 1984. First, there are indications that abundance was higher in the middle years of the 1950's than at the beginning or at the end. Then, following a prolonged period of low abundance, the stock increased in the mid-1960's. This coincided with the maturity of the dominant 1961 year class and the buildup of the foreign fisheries which might have been expected to reduce the abundance of eggs and larvae in subsequent years. This, however, was not the case as the surveys revealed high levels of abundance for the years 1972-1980, with the isolated exception of 1976 when the survey revealed a precipitous decline in larvae. Not only were larvae scarce in 1976, but they were found within only a small area. This suggests that the area used for spawning in 1976 was itself greatly reduced.

The low index values for 1976

[4]Stepanenko, M. A. 1979. Estimates of spawning biomass and reproductive conditions of Pacific hake and California anchovies in 1978. Unpubl. manuscr., Pacific Scientific Research Institute of Fisheries and Oceanography (TINRO), Vladivostok, U.S.S.R.

[5]Stepanenko, M. A. 1981. Assessment of stocks and reproductive conditions of Pacific hake and California anchovy in 1981. Unpubl. manuscr., Pacific Scientific Research Institute of Fisheries and Oceanography (TINRO), Vladivostok, U.S.S.R.

proved, however, to be a 1-year phenomenon, as the index values increased sharply in 1977 and remained very high through 1980. This reflects the continued influence of the large 1970 and 1973 year classes. The extremely low levels of abundance of larvae in 1982 and 1983 suggest that the contribution of the 1977 year class (which was strong according to Bailey and Francis (1985) and Beamish and McFarlane (1985)) has been much lower than expected. It is not known whether the scarcity of larvae in 1982 and 1983 (and 1976) was caused by an unexpected reduction of the respective spawning biomasses, by impaired spawning of normal-sized spawning populations, by poor survival of eggs and larvae from normal-sized spawning populations, by displacement of eggs and larvae from the survey area, or by a combination of these and other possible factors. That the extremely low indices of larvae can be the first signal of an impending year-class failure is supported by the work of Bailey and Francis (1985) who reported that recent age composition samples from the commercial fishery indicate that the 1976 year class is practically nonexistent.

Table 4.—The CalCOFI time series of Pacific whiting spawning biomass indices based on the occurrence of whiting larvae in the ichythoplankton, 1951-84[1].

Year	Percentage of positive stations	Number of larvae/10m²	Survey months
1951	23	32	Jan.-Feb.
1952	30	86	" "
1953	44	109	" "
1954	54	55	" "
1955	75	158	" "
1956	52	216	" "
1957	44	216	" "
1958	55	83	" "
1959	45	52	" "
1960	43	30	" "
1961	31	34	January
1962	48	77	"
1963	57	65	"
1964	49	26	"
1965	49	63	"
1966	52	170	Jan.-Feb.
1968	54	270	January
1969	49	91	Jan.-Feb.
1972a	31	67	" "
1972b	57	406	March
1975a	36	252	January
1975b	54	434	March
1976	16	68	February
1977	76	321	March
1978	70	461	"
1979	84	550	"
1980	56	485	Feb.-Mar.
1981	44	136	February
1982	26	18	Jan.-Apr.
1983	28	10	Feb.-Apr.
1984	35	175	Feb.-Mar.

[1]Sources:
Stauffer, G. D., and P. E. Smith. 1977. Indices of abundance of Pacific hake from 1951 to 1976. Southwest Fish. Cent. Admin. Rep. LJ-77-2. Southwest Fisheries Center, NMFS, NOAA, P.O. Box 271, LaJolla, CA 92038.

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Recruitment of Pacific Whiting, *Merluccius productus*, and the Ocean Environment

KEVIN M. BAILEY and ROBERT C. FRANCIS

Introduction

Because Pacific whiting, *Merluccius productus*, is one of the most abundant fishes along the west coast of North America, its population dynamics have important consequences, not only for fishermen, but for the total ecosystem. Typically, the whiting population fluctuates markedly. For whiting and, indeed, for many other fish species, recruitment variability is the major component in stock dynamics and has a greater impact on stock production than variability in either growth or mortality (Doubleday, 1980). Whiting are long-lived and highly fecund, and their spawning produces billions of eggs each year. Since mortality during the first months of life is very high, changes in survival rates of only a few percent during egg and larval life probably generate large variations in recruitment (Gulland, 1965). It is believed that these changes in survival of early stages are the dominant cause of fluctuations in stock biomass. Like many other gadoids, recruitment of whiting does not appear to be closely coupled to the size of the spawning stock, at least over the range of stock sizes observed to date.

Pacific whiting are normally found over the continental shelf/slope within the California Current system, roughly from lat. 25° to 50° N. Most adults spend the summer months in the northern part of the range. In autumn, adults migrate southward from the Pacific Northwest waters to spawn in winter off the coasts of central, southern, and Baja California. After spawning, large fish migrate as far north as Vancouver Island, while eggs, larvae, and juveniles are found off the coast of the Californias.

The unique life history of Pacific whiting, as well as a good time series of data on planktonic, juvenile, and adult stages, has created an unusual opportunity to examine the relationship of the ocean environment to population dynamics. These data include larval surveys from the California Cooperative Oceanic Fisheries Investigations (CalCOFI) program of the Southwest Fisheries Center (since 1950) of the National Marine Fisheries Service (NMFS), midwater trawl surveys from the California Department of Fish and Game (CDFG) (since 1966), bottom trawl and midwater trawl/hydroacoustic surveys from the NMFS Northwest and Alaska Fisheries Center (NWAFC) (since 1965), and commercial fishery data collected by the NWAFC observer program (since 1973). In addition, one of the world's most extensive time series of oceanographic data, compiled by the NMFS Pacific Environmental Group, is available for the California Current region. Recruitment studies coordinated at NWAFC have combined analyses of the above data with modeling and laboratory and field studies to examine the causes and consequences of population fluctuations of whiting.

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Fluctuations of the Whiting Stock and Year-class Strength

Recruitment to the whiting population can be quite variable, as strong year classes appear infrequently and dominate the population for 5-7 years (see Figure 1 in Francis and Hollowed, 1985). Between the years 1970 and 1977, estimates of year-class strength are available from cohort analyses. The estimated number of 3-year-old recruits ranged from 0.16 to 2.37 $\times$ 10^9 individuals, a difference of about fifteenfold (Fig. 1). Prior to 1973, commercial catch data were not available and a year-class strength index (YCI) was calculated by totaling the contribution of 3-, 4-, and 5-year-old fish to research trawl surveys in successive years (Bailey, 1981). Figure 1 shows that the YCI is closely related to the estimate of the number of 3-year-old recruits calculated from cohort analysis where data for both indices exist ($R = 0.152 + 1.890$ YCI, $r^2 = 0.89$). Using this relationship, the time series for recruit abundance has been extrapolated back to 1960. Over this 18-year time series, estimates of recruitment range from about 0.03 to 2.82 billion age-3 individuals, which is a difference of about ninety-fold. In this time series, very strong year classes appeared in

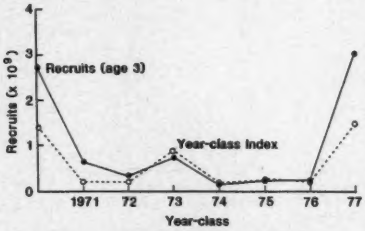

Figure 1.—The number of 3-year-old recruits estimated by cohort analysis (dots) compared with the index of year-class strength (circles), 1970-77.

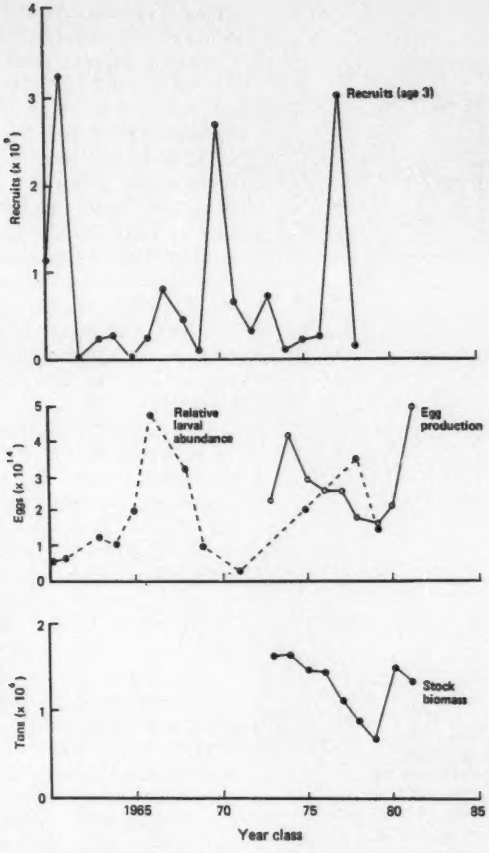

Figure 2.—The number of 3-year-old recruits (top), theoretical number of eggs produced by the spawning stock compared with larval abundance (middle), and estimated adult stock biomass (bottom) by year, 1960-81.

1961, 1970, and 1977. The years 1960, 1967, and 1973 were moderately strong year classes (Fig. 2). Preliminary data indicate that the 1980 year class is also very strong.

Estimates of stock biomass (age 3 and older fish) are also available from 1973 to 1981 (Fig. 2). Over this period, stock biomass declined to its low point in 1979 due to poor recruitment of the 1971-72 and 1974-76 year classes. In 1979 the stock was only 43 percent of its biomass in 1973. The stock was maintained by a moderately strong year class in 1973, and by the persistence of older fish from the 1970 year class. These two year classes totally dominated catches from 1974 to 1979. Whereas declines in stock biomass appear to be gradual (due to the longevity of whiting and the continued persistence of strong year classes), increases in stock biomass can be dramatic. For example, between 1979 and 1980 the estimated adult stock biomass approximately doubled due to the strong recruitment of the 1977 year class.

Rough estimates of spawning stock biomass can be reconstructed back to 1960 from historical ichthyoplankton surveys. This method assumes that the population of larvae is dominated by yolk-sac stages, that the number of larvae reflects the number of eggs spawned, and that the number of eggs spawned is directly related to the adult stock biomass. Since the surveys did not always occur in the same months each year, the numbers have been adjusted to account for time of survey. The analysis shows that peaks in larval abundance occurred in 1964-66 and in 1973-78 corresponding to the maturation and spawning of the strong year classes of 1961, 1970, and 1973. It is also possible to calculate the theoretical number of eggs produced by the population from the results of the cohort analysis (Fig. 2). These calculations tend to agree with the results of the larval surveys. However, reports of larval abundance from 1981 to 1983 indicate their numbers have declined despite the maturation of the strong 1977 year class. Since these recent surveys were conducted in March, their results may not be comparable to the earlier estimates from January and April surveys. Furthermore, 1981-83 were anomalously warm years, and spawning could have been earlier or farther north than the area covered by the March surveys. Alternatively, larval survival may have been extremely poor in these years, and larval abundance did not reflect actual spawning. Preliminary data do indicate that the 1981-1983 year classes will be weak.

Fluctuations in recruitment are apparently not a function of spawning stock biomass, as there has been no consistent trend in the relationship of these two variables. For example, the strong year classes of 1961 and 1970 were spawned by low biomass stocks, and the strong year classes of 1977 and 1980 were spawned by high biomass stocks. Furthermore, weak year classes were produced both in years of high (1966, 1968, 1975, 1976) and low (1963, 1964, 1971, 1979) spawning stock biomass.

The relative strength of a year class appears to be determined within the first months of a cohort's life. From

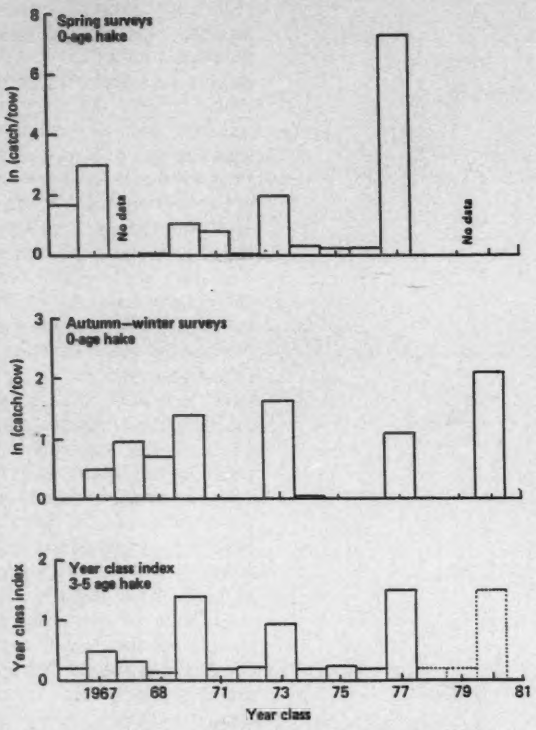

Figure 3.—Relative abundance of 0-age whiting caught in California Fish and Game midwater trawl surveys in spring (top) and autumn-winter (middle) compared with the index of year-class strength (bottom), 1966-80. Source: Bailey, K., K. Mais, and R. Francis. 1984. Incidental catches of 0-age Pacific whiting in midwater trawl surveys and forecasting year class strength. Unpubl. manuscr. Northwest Alaska Fish. Cent., NMFS, NOAA, Seattle, Wash.

analysis of midwater trawl data taken in CDFG spring and fall surveys, there is an evident relationship between postlarval abundance in the first 3-6 months (spring) of life and subsequent recruitment 3-5 years later (Fig. 3); postlarval young of the year appeared especially abundant in the spring months of 1967, 1970, 1973, and 1977. No survey data were available for spring 1980. By the autumn-winter in the first year of life, the 1970, 1973, 1977, and 1980 year classes appeared strong compared with all other year classes, and are indicative of their strength after recruitment to the fishery.

The data from these trawl surveys were collected from lat. 30° to 35°N, and are reported as catch/haul, uncorrected for duration of tow or net opening. The CDFG surveys were not systematically sampling for juvenile whiting, but recruitment strength is indicated by survey catches due to the extreme dynamics exhibited by the whiting population; i.e., there is either very good or very poor survival of larvae. More systematic surveys could be extremely useful for more precise management of the fishery, if and when that need arises.

Factors Affecting Year-Class Strength

Since recruitment appears to be established in larval life, a brief review of the larval environment is appropriate; a more complete description is available in Hickey (1979). The California Current system is characterized by four main currents. South of Point Conception, the surface California Current flows toward the Equator all year. North of Point Conception, this southward flow is replaced in winter by the poleward-flowing Davidson Current. In southern California a nearshore poleward-flowing countercurrent combines with the California Current to form the Southern California Eddy. Finally, there is a subsurface poleward flow known as the California Undercurrent.

The California Current system is driven by winds, which tend to blow poleward in winter and equatorward in summer. Upwelling events may occur during prolonged periods of strong equatorward winds (Bakun, 1973, 1975). These winds also cause advection, or horizontal movement, of cold, low-salinity water (subarctic water mass) equatorward and offshore. During relaxation of these winds or when winds blow poleward, warm saline water (the subtropical or Central Pacific water masses) flows poleward and spreads inshore. Since each water mass has its own characteristic planktonic community (Brinton, 1981), advective events have a strong effect on the composition and abundance of the zooplankton. Zooplankton biomass is normally highest in the northern portion (Point Conception to Point Reyes) of the region inhabited by whiting larvae, and abundance decreases in offshore and equatorward directions (Chelton, 1982). Large-scale variability in zooplankton abundance does not appear to be closely coupled to upwelling simply as an influx of nutrient-rich water, but rather to large-scale advective and flow patterns (Chelton, 1981; Bernal, 1981).

Spawning of whiting within the California Current system, as determined by the distribution of eggs and small larvae, appears to take place from Janauary to March in a region of transitional nature between central and Baja California. However, in

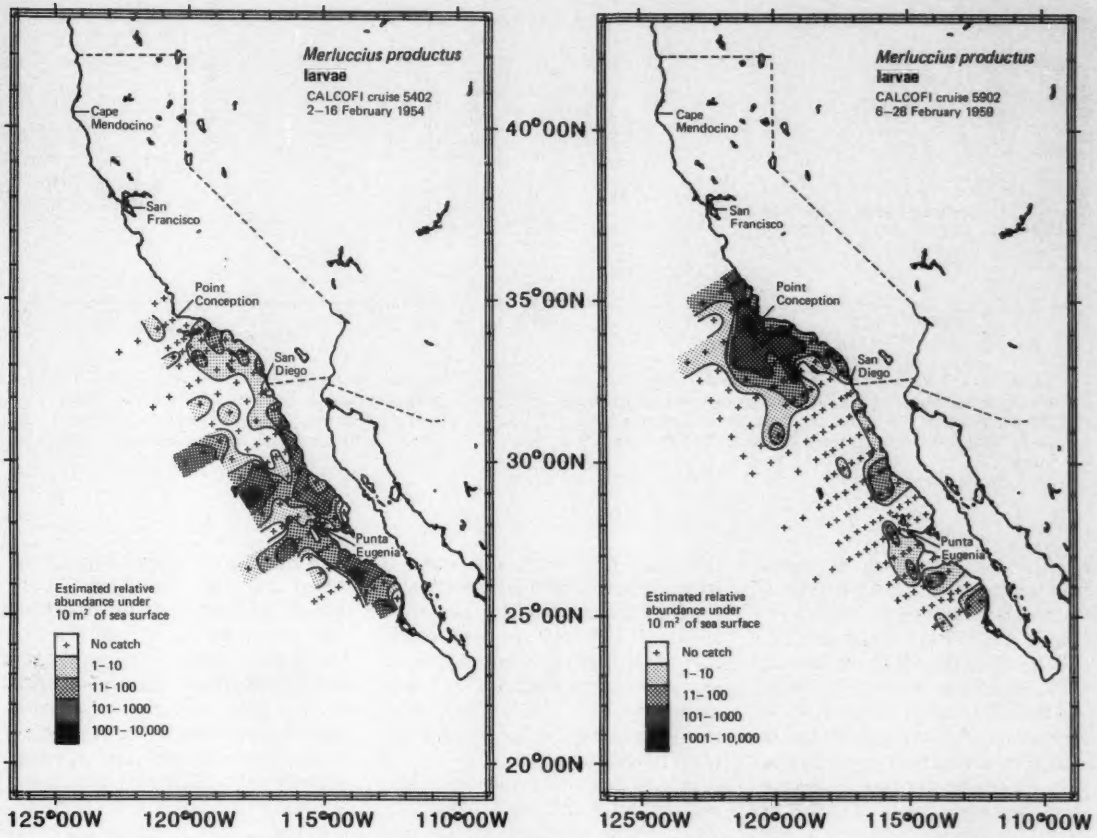

Figure 4.—Comparison of the north-south, onshore-offshore distribution of whiting larvae in a cold year (1954) and a warm year (1959). Source: Ahlstrom 1969.

periods of unusually warm or cold temperatures, spawning may occur considerably to the north or south, respectively. For example, in 1954, a cold year, larvae were distributed southward and offshore compared with larval distribution in 1959, a warm year (Fig. 4). As sampling for spawning adults has been unsuccessful, it is not known if larval distribution is a result of advection or actual spawning location.

After hatching, whiting larvae live below the upper mixed layer. As a consequence of living in cold water, the growth and developmental rates, metabolic rates, and energy requirements of whiting larvae are low (Bailey, 1982) compared with other larvae such as anchovy and mackerel living in the same geographic region but located in the warm upper mixed layer. Whiting larvae also have relatively large mouths compared with other larvae and are able to feed on a wide spectrum of food particles (Hunter, 1981; Sumida and Moser, 1980).

The determination of whiting year-class strength appears to be related to environmental conditions in the California Current ecosystem within the first few months of life. However, our present understanding of this relationship is probabilistic and not deterministic. Previous studies using linear regression analysis showed direct relationships between environmental conditions and recruitment, but these studies were limited by a short time-series (Bailey, 1981). The inverse relationship between recruitment and upwelling or temperature has not remained as strong in recent years. However, it appears that certain conditions are required for good larval survival, while other conditions apparently decrease survival. From 1960-77, cold years produced weak year classes in 7 of 7 cases (Fig. 5). On the other hand, all strong year classes

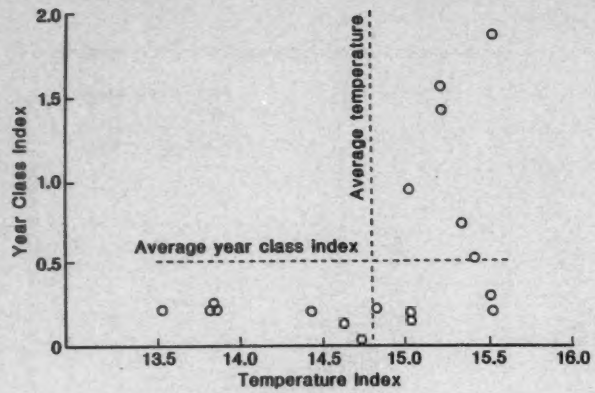

Figure 5.—The year-class index as related to the mean sea-surface temperature in the area and at the time of spawning (Marsden square 120-2, January-March). Dotted lines are the mean values for the sea-surface temperature and year-class index.

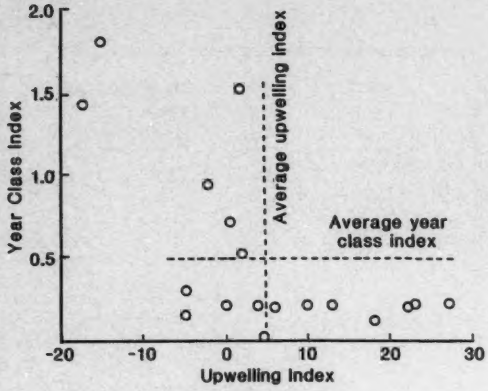

Figure 6.—The year-class index as related to the upwelling index in the area at the time of spawning (36°N, January). Dotted lines are the mean values for the upwelling index and the year-class index.

resulted from spawning in warmer than average years, although not all warm years resulted in strong year classes. Preliminary qualitative data indicate that the 1978 (warm) and 1979 (warm) year classes will be weak, and the 1980 (warm) year class will be very strong. We may hypothesize that cold years consistently produce weak year classes due to the presence of some dominant large-scale environmental conditions, and warm years may produce strong year classes, but there is much variability in warm years due to the multiplicative effects of many environmental forces acting on larval survival.

A comparison of sea-surface temperatures in warm years that produce strong year classes with cold years that produce weak year classes shows marked differences. In cold years, equatorward flow and upwelling are dominant events, pushing the 60° F isotherm south to Point Eugenia (27°N). Isotherms tend to be oriented parallel to the coast, and the nearshore water is cold in the region where whiting normally spawn. By contrast, in warm years the 60° F isotherm lies at the southern end of the Los Angeles Bight (30° N), isotherms are nearly perpendicular to the coast, and nearshore water is warm. These marked differences may 1) affect the location of spawning by adults, 2) influence the local conditions that determine larval survival (e.g., food production, predator abundance, etc.), and 3) reflect events that themselves influence survival (e.g., advection).

In cold years of strong upwelling, whiting larvae are often found offshore. Either advection of eggs and larvae or spawning by adults offshore may be detrimental to larval survival. Although a strong linear correlation does not exist between year-class strength and offshore transport, all strong year classes were spawned in years of lower-than-average upwelling (Fig. 6). Strong upwelling has always resulted in weak year classes. Unfortunately, these effects are difficult to separate from the covarying effects of temperature. Some evidence exists indicating that whiting larvae located offshore have slower growth rates and may not be surviving (Bailey, 1981). Furthermore, by the summer after spawning, virtually all surviving postlarvae are located over the continental shelf or near islands in the Los Angeles Bight. From CDFG midwater trawl surveys, it is seen that all large catches of 0-age whiting are inshore over the shelf/slope, even though eggs and larvae may have been distributed far offshore (Fig. 7). Theilacker[1] reports from histological studies that 60-70 percent of first-feeding jack mackerel, *Trachurus symmetricus*, larvae in the open ocean (200 miles offshore) are starving, whereas only 6-12 percent near islands or banks in the Los Angeles Bight are starving. Also supporting the hypothesis that larvae located offshore are starving is the Arthur (1977) study demonstrating that the abundance of zooplankton suitable as larval food decreases in an offshore direction.

Spawning by adults southward or advection of eggs and larvae in that direction may also be detrimental to survival. Zooplankton abundance decreases toward the south where the continental shelf is also narrow, limiting suitable juvenile habitat. Even though larvae may be abundant

[1]Theilacker, G. 1984. Starvation-induced mortality of young sea-caught jack mackerel *Trachurus symmetricus*, determined with histological and morphological methods. Southwest Fish. Cent., NMFS, NOAA, La Jolla, Calif. (Abstr. presented at Int. Symp. on the Early Life History of Fishes, Univ. Brit. Col., Vancouver, B.C. May 6-10, 1984.)

off Baja California in some years, large catches of juveniles there are relatively uncommon.

Growth may be poor in offshore regions; however, there is no evidence that surviving larvae or postlarvae in nearshore regions that produced strong year classes grew any faster compared with larvae producing weak year classes. Although sample sizes are small, a comparison of length vs. otolith increments from 1977 to 1979 shows wide variability with no apparent differences in growth between the strong 1977 year class and the weak 1978 and 1979 year classes (Fig. 8). In fact, there is some evidence that strong cohorts may grow slower as juveniles due to density-dependent effects (Dark, 1975). There have been no comparisons of larval growth in cold years as opposed to the above warm years. However, in cold years, due to offshore spawning or transport, a larger proportion of larvae may inhabit waters where food is less plentiful, causing a lower proportion of the population to survive. Although counting otolith increments may be a valuable tool for ageing fish larvae, measuring growth rates from otolith increments and body lengths may be inadequate for comparisons due to shrinkage of larvae during sampling (Theilacker, 1980); a more sensitive technique may be histological examination of larvae for evidence of starvation (Theilacker, 1978; O'Connell, 1980).

Little is known about predators of whiting eggs and larvae, and much less is known of their impact on the population off the California coast. Hunter (1981, 1984) reviewed the potential predators of anchovy and gadoids. Hunter and Kimbrell (1980) found that anchovy adults consumed large numbers of their own eggs;

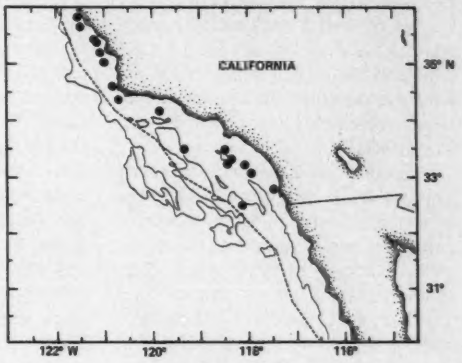

Figure 7.—The location of catches of juvenile whiting >1000 fish/haul in California Fish and Game midwater trawl surveys. The area generally covered by the surveys is surrounded by the dashed line.

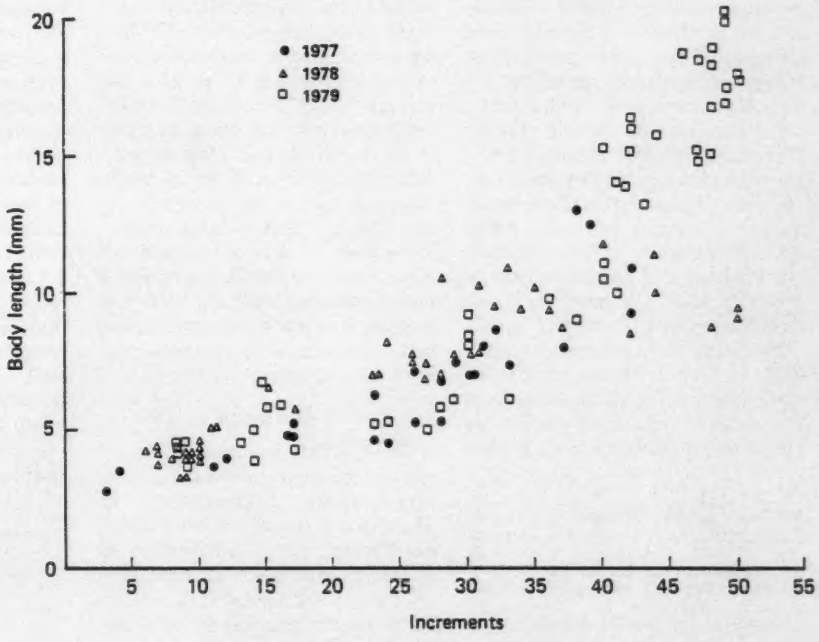

Figure 8.—The length of whiting larvae as related to otolith increments in 3 years, 1977-79.

however, Hunter[2] reports finding few if any whiting eggs. A study of predation on whiting eggs and larvae by invertebrate animals in Puget Sound attributed a significant decline in egg and larval survival to an increase in the predator population. The predatory copepod *Euchaeta elongata* was identified as a major predator on the basis of melanin pigments from fish larvae in its guts. Yolksac and starved first-feeding whiting larvae were the stages most vulnerable to *E. elongata* in simultaneous laboratory studies. Slowed growth and starvation were identified as environmentally controlled processes which could extend the duration that larvae are in these vulnerable stages (Bailey and Yen, 1983).

Predation on eggs and larvae of some species is currently considered to be a major source of larval mortality that can generate variability in recruitment. Because of their small size, gadoid larvae, in general, are extremely vulnerable to predators when compared with the larger larvae of herring and some flatfish (Bailey, 1984). Considering this importance, there is a disproportionate lack of research on predation of larvae relative to studies of larval feeding. Several new methods show great promise in studies of predation, including immunological techniques (Feller, 1982), identification of whole larvae (Purcell, 1981), fish otoliths (Yen[3]), and fish pigments (Bailey and Yen, 1983) in predator guts, and encounter rate models (Bailey and Batty, 1983). Given development of these methods, our knowledge of the importance of predation over the next few years should increase dramatically.

Predation on juvenile whiting probably is not a major source of variability in recruitment. First, from the evidence presented above, we believe that the strength of a year class is largely determined within the first few months of hatching. Second, juvenile whiting do not appear to be the major prey of large fishes in the California Current system. Third, changes in the abundance of large predators occur over a long time period compared with the interannual variability in recruitment. Fourth, some rough calculations show that one major type of predator, marine mammals, has little impact on the population. The maximum annual consumption of whiting by its three main mammal predators, California sea lions, northern sea lions, and northern fur seals, is about 100-200 million kg given a daily consumption rate of 10 percent body weight per day (Bailey and Ainley, 1982). Given a more conservative ration of 5 percent body weight per day and an average fish weight of 0.32 kg (most prey are 2- to 4-year-olds) this calculates to 150-300 million fish. Of these, perhaps 50 percent will be from a single year class (80-150 million fish). These numbers are 20-40 times smaller than the rather conservative estimates of recruitment that result from a cohort analysis. These predators may have an effect on weak year classes; however, when whiting are not abundant, mammals appear to switch to feeding on rockfish and perhaps squid (Bailey and Ainley, 1982; Antonellis and Perez, In press). When a strong year class appears, nearly 90 percent of the diet of marine mammals may be composed of whiting (Bailey and Ainley, 1982). Regardless of this high predation pressure, strong year classes survive to remain abundant up to age 10. Consequently, it appears that a strong year class can swamp the predatory capacity of the ecosystem.

Discussion

Bernal (1981) evaluated the importance of the interaction of the physical oceanographic environment with planktonic organisms in the California Current. He concluded that interannual variability in the strength of the current and related flow patterns determine the behavior of the biological component of the ecosystem. Furthermore, he hypothesized that this ecosystem might not operate under equilibrium conditions, and that classic interactive biological processes, such as competition and predation, might play a secondary role in regulating the abundance of species when compared with the role of physical conditions. Whereas Bernal's thesis related to zooplankton, the importance of environmental variability (Parrish et al., 1981) and the lack of equilibrium conditions might apply also to fish production in the California Current region. Recent developments in ecological theory (Lewin, 1983) concur with the idea that the assumption of equilibrium conditions is not valid in ecosystems where environmental perturbation may be a dominant feature.

In the California Current, the dynamics and production of fish populations are strongly influenced by environmental processes. These processes may affect the feeding of young fishes and predation upon them. This argument is supported by the dynamics of the whiting stock; recruitment is apparently tied to environmental conditions during early life, and, at our current state of understanding, predatory or competitive interactions involving older juveniles appear to be of secondary importance to recruitment. However, at low levels of stock abundance, predation may have a significant effect on recruitment. The influence of favorable environmental years is not restricted to observations of whiting, but also is seen for many other species. For example, where information on relative recruitment of different species exists, it is obvious that 1961, 1970, and 1977 were exceptionally good recruitment years for many species from southern California to the Gulf of Alaska (Hollowed et al.[4]).

[2]Hunter, J.R. 1983, Southwest Fish. Cent., NMFS, NOAA, La Jolla, Calif. Pers. commun.
[3]Yen, J. 1984. Predation on larvae of the cod (*Gadus morhua* L.) by the predatory copepod, *Euchaeta norvegica*. Unpubl. manuscr. Department of Oceanography, Univ. Hawaii, Honolulu, Hawaii 96822.
[4]Hollowed, A., K. M. Bailey, and W. S. Wooster. 1984. Coherence in year-class strengths of fishes along the west coast of North America. Unpubl. manuscr. Northwest Alaska Fish. Cent., NMFS, NOAA, Seattle Wash.

Although more is known about the dynamics of the whiting stock than about most other fishes in the eastern North Pacific, little is known about the underlying causes of recruitment fluctuations. It is apparent that cold years demonstrate little variability in recruitment and the likelihood of a strong year class is small. In warm years the variability in recruitment is much higher with greater probability of a strong year class. Compared with warm years, spawning in cold years is further south, eggs and larvae develop more slowly, predation mortality may be higher, and advection offshore or southward may be more significant. How these conditions result in the relative success or failure of a year class is not presently well understood. Considering the importance of whiting as a keystone species to the California Current ecosystem, more research is needed. This research should include work on 1) temporal and spatial variability in spawning related to environmental conditions; 2) comparative growth and starvation condition of larvae in areas hypothesized to be favorable and unfavorable nursery grounds, i.e., onshore vs. offshore and the Los Angeles Bight vs. coastal Baja California; 3) the process of egg and larval advection in relation to oceanographic conditions; 4) predation on eggs and larvae and development of techniques to quantify predation effects; 5) the biology of juvenile whiting, including studies of otoliths to determine the birthdate distribution of survivors; 6) development of midwater trawl surveys for estimation of prerecruit abundance; and 7) effects of predators on the dynamics of juvenile whiting, especially at low levels of whiting stock abundance.

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Trophic Role of the Pacific Whiting, *Merluccius productus*

P. A. LIVINGSTON and K. M. BAILEY

Introduction

Pacific whiting, *Merluccius productus*, constitutes the most abundant groundfish resource off the west coast of the continental United States (Nelson and Larkins, 1970). Thus, it may play a central role in the dynamics of biomass transfer in the food web of the California Current system. Previous studies have identified whiting as a predator on commercial fish and shrimp (Gotshall, 1969 a, b; Alton and Nelson, 1970; Outram and Haegele, 1972; Livingston, 1983). Additionally, whiting may provide a significant food source for other fish, marine mammals, and birds. Therefore, changes in whiting abundance or production may affect the abundance or production of the whiting's predators and prey. Here, we examine the food web links which involve Pacific whiting and comment on their importance.

Pacific Whiting: The Predator

General Prey Items

Several studies over the past 20 years have examined various aspects of the food habits of Pacific whiting. A general description of prey types consumed by whiting is summarized from the results of these studies in Table 1.

Gotshall (1969a) sampled a wide size range of whiting over 1 year on the shrimp beds of northern California. These whiting consumed (by volume) mostly pandalid shrimp (44 percent), fishes (29 percent), and euphausiids (18 percent). Off Washington and Oregon, Alton and Nelson (1970) found that the whiting diet (in terms of weight) consisted of 53 percent euphausiids, 37 percent fish (mostly eulachon, *Thaleichthys pacificus*), and only 8 percent pandalid shrimp. Similarly, Outram and Haegele (1972) reported a declining frequency of occurrence of shrimp (3 percent) in whiting stomachs taken southwest of Vancouver Island, British Columbia. There, euphausiids occured in 94 percent of the stomachs sampled, and Pacific sand lance, *Ammodytes hexapterus*, in 26 percent. Livingston (1983) also noted the decreasing importance of shrimp (< 5 percent by weight) and the increasing importance of euphausiids (15-98 percent) and schooling fish, such as eulachon and Pacific herring, *Clupea harengus pallasi* (13-69 percent), in the diets of adult whiting off Oregon, Washington, and British Columbia.

Overall, the common food item consumed by adult whiting over its range of major abundance (from California to British Columbia) was euphausiids. Other items dominated the diet, depending on the area: Pandalid shrimp were the major dietary component in northern California, while schooling fish were important in the food of whiting from Oregon to British Columbia. The general tendency seems to be for whiting to consume prey items which occur in patches or schools, such as euphausiids and pelagic fish (like eulachon and herring). Additionally, the majority of whiting prey, such as pandalid shrimp and the pelagic fishes, are also euphausiid predators (Pearcy, 1970; Wailes, 1936; Barraclough, 1964). Thus, euphausiids appear to be the most important item in describing the diet of adult whiting; they attract not only whiting but also

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Table 1.—Summary of studies on the feeding habits of Pacific whiting.

Study	Sampling location	Sampling period	Whiting size range (cm)	Major prey in % wt. (W), % vol. (V), or % freq. occur. (FO)
Gotshall, 1969a	N. California	July 1964-Sept. 1965	10-81	(V) 44% pandalid shrimp, 29% fish, 18% euphausiids
Alton and Nelson, 1970	Wash., Oregon	May-Sept. 1964-65	46-66	(W) 8% pandalid shrimp, 37% fish, 53% euphausiids
Outram and Haegele, 1972	SW Vancouver Isl.	August 1970	42-71	(FO) 3% pandalid shrimp, 26% sand lance, 94% euphausiids
Livingston, 1983	Wash., Oregon	April-July 1967	49-50	(W) < 1% pandalid shrimp, 13% fish, 86% euphausiids
	California	October 1980	10-20	(W) 98% euphausiids
	Oregon	April-May 1980	35-45	(W) 98% euphausiids
	Oreg., Wash., SW Vancouver Isl.	April-Sept. 1980	45-65	(W) 3% pandalid shrimp, 69% fish, 15% euphausiids
Sumida and Moser, 1980	California	March 1975	0.3-1.1	(V) 74% adult copepods, 17% copepodites, 5% copepod nauplii

other organisms which then become vulnerable to whiting predation.

Changes in Diet With Whiting Size

Pacific whiting larvae possess relatively large mouths that enable them to feed on a wide range of prey sizes from 50-400 μm in width. Sumida and Moser (1980) found that the food of whiting larvae consisted primarily of adult copepods (74 percent by volume). Other prey items were copepod eggs, copepodids, and copepod nauplii.

The diet of juveniles has not been studied very extensively. Livingston (1983) discovered juvenile whiting in the 100-200 mm size range fed almost exclusively on euphausiids off California (98 percent by weight).

As noted previously, adults feed on euphasiids, pelagic fishes, and pandalid shrimp. Several studies have shown that the weight or frequency of these items in the diet may change with increasing adult whiting length. Gotshall (1969b) calculated the average number of pandalid shrimp per whiting stomach by 100 mm size classes of whiting off northern California. Whiting 400-490 mm in length had about 1-2 shrimp per stomach, while stomachs from whiting >500 mm in length contained 2-8 shrimp each. Off British Columbia, the frequency of occurrence of schooling fish increased from 21.8 percent in whiting 420-510 mm in length to 34.4 percent in whiting 620-710 mm in length (Outram and Haegele, 1972). Figure 1 shows the differences mainly in the percent by weight of fish in the diets of whiting. Whiting <450 mm in length ate virtually no fish. Whiting in the 450-550 mm size group ate 37 percent fish by weight off Oregon and 66 percent fish by weight off Washington and Vancouver Island. Whiting >550 mm consumed 94 percent and 90 percent fish by weight, respectively, in the two areas. Figure 2 depicts the increase in frequency of occurrence of herring in whiting stomachs of increasing size. All these studies point to a change in diet occurring when the whiting reach a length of about 400-500 mm. As their size increases, whiting seem to consume larger prey such as fish or shrimp and fewer euphausiids.

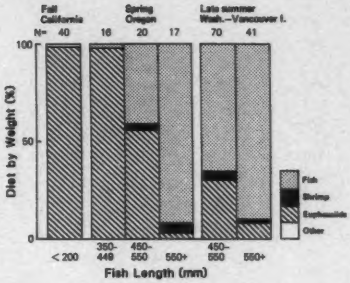

Figure 1.—Percentage by weight of major prey categories in the diet of Pacific whiting, *Merluccius productus*, for different whiting length groups sampled at various locations in 1980.

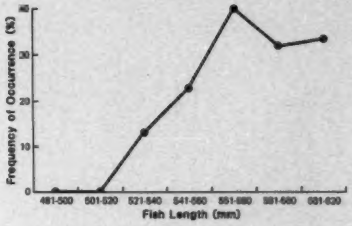

Figure 2.—Percent frequency of occurrence of Pacific herring, *Clupea harengus pallasi*, in stomachs of different whiting length groups sampled in late summer 1980 off Washington and Vancouver Island, B.C.

It is possible to quantify whiting's prey size preference by calculating the frequency distribution of predator weight to prey weight ratios, as described in detail by Ursin (1973), and actually computed for whiting by Livingston (1983). Basically the method involves calculating predator-prey size ratios using information on the total weight in grams (W_j) and total number (ΣN_j) of each prey type j in a collection of predator stomachs. The individual mean weight of each prey type ($\bar{w}_j$) is calculated and compared with the mean predator weight ($\bar{w}_i$). The frequency distribution of the ratios of predator weight to prey weight ($\bar{w}_i/\bar{w}_j$) is usually log-normal in shape. Therefore a plot of $\ln(\bar{w}_i/\bar{w}_j)$ vs. ΣN_j should produce a normal curve.

However, the proportion of a prey item in a predator's diet is a function not only of the predator's choice of that prey but also of the availability of the prey (Lawlor, 1980). So the observed proportions of prey items in a predator's stomach reflect predator preference only when the abundances of all prey items in nature are equal. This situation can be simulated by assuming the numbers of each prey type in the environment are inversely proportional to prey weight (Ursin, 1973). Thus, to offer equal numbers of each prey size to a predator one would multiply the total number of each prey type j (ΣN_j) by the mean weight of each prey ($\bar{w}_j$). The result would then be divided by $\bar{w}_i$ to adjust for predator size.

Figures 3-5 show the results of these calculations for different size groups of whiting. The solid lines depict the frequency distributions of predator-prey size ratios uncorrected for prey availability. The dashed lines show the shapes of curves resulting from simulating the effects of offering equal numbers of each prey size to whiting predators.

Whiting <200 mm whose diet was mostly euphausiids, have a narrow prey-size selection curve reflecting the limited size range of items in their diet (Fig. 3). The selection curve (solid line) for this size group of whiting follows the preference curve (dashed line) indicating these whiting are actually consuming their preferred prey.

Intermediate-sized whiting, 350-549 mm in length, have a selection curve (Fig. 4) which reflects the numerical dominance of euphausiids in their actual diet. The preference curve shifts and is bimodal, with the largest mode at a predator-prey size ratio of about 100:1, and the second mode reflecting

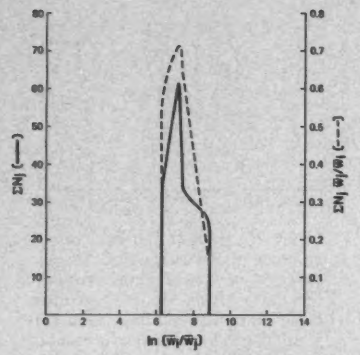

Figure 3.—Frequency distribution of predator-prey size scores for Pacific whiting less than 200 mm as the predator, with an average weight ($\bar{w}_i$) of 13.2 g, under natural (line) and simulated (dashes) conditions.

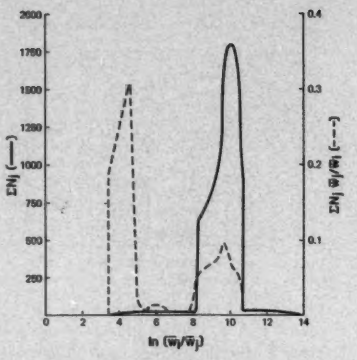

Figure 4.—Frequency distribution of predator-prey size scores for Pacific whiting 350-549 mm in length as the predator, with an average weight ($\bar{w}_i$) of 876.2 g, under natural (line) and simulated (dashes) conditions.

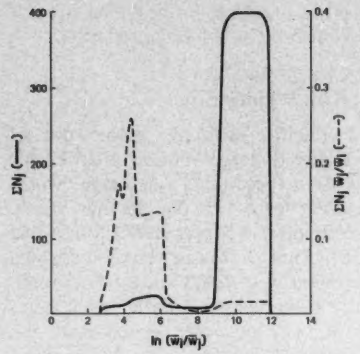

Figure 5.—Frequency distribution of predator-prey size scores for Pacific whiting larger than 550 mm as the predator, with an average weight ($\bar{w}_i$) of 1,441.3 g, under natural (line) and simulated (dashes) conditions.

a continued preference for euphausiids. A non-normal selection curve shape can arise when prey items occur in such dense patches that the predator may consume more than one prey item at a time (Ursin, 1973).

Large whiting (>550 mm) also have a selection curve (Fig. 5) which shows the numerical dominance of euphausiids in their diet. The preference curve looks more closely unimodal with the main peak corresponding to a predator-prey size ratio of 130:1 (about the ratio of a large whiting predator to a herring-sized prey). These whiting appear to prefer large-sized prey, but will actually consume mostly euphausiids—possibly because the dense nature of euphausiid patches allows whiting to exploit patches as a food source efficiently.

Daily Ration

To determine the impact a predator stock has on a prey population, it is important to calculate the total annual consumption of a particular prey by the whole predator stock. This type of calculation requires several types of information: An estimate of the size of the predator stock; a determination of the relative contribution of the prey item in the predator's diet through stomach content analysis; and an estimate of the total amount of food consumed by the predator, which requires the calculation of daily ration.

Livingston (1983) calculated daily ration for whiting from field data, which requires stomach samples taken at different times throughout the day. The gastric evacuation rate estimate for whiting (required for the calculations) uses the Elliott and Persson (1978) model which assumes an exponential, temperature-dependent evacuation rate, R. If stomach samples are collected at intervals of t hours, the mean stomach content weight as a percentage of fish weight, S_i, in each interval i is calculated for a total of m intervals over the 24-hour period. The daily ration, ΣC_i (in terms of percent body weight), is derived from:

$$\Sigma C_i = 24\bar{S}R,$$

where $\bar{S} = \Sigma S_i/m$. Durbin and Durbin's (1980) estimate of the relationship between gastic evacuation rate (R) and water temperature (T) for marine fish eating small food organisms was used for the calculation where:

$$R = 0.0416e^{0.105T}.$$

Livingston's (1983) estimate of the daily ration for whiting, using Equations (1) and (2), was equal to 2.5 percent body weight per day during the feeding season for a Pacific whiting with an average length of 500 mm, assuming the average water temperature at sample collection time and depth to be 8.2°C.

This estimate compares with those for a similar fish in the northwest Atlantic, silver whiting, *Merluccius bilinearis*, whose daily ration values range from 0.6 to 2.7 percent body weight per day (Durbin et al., 1983; Cohen and Grosslein, 1981; Pennington, 1981), although the Pacific whiting's estimate falls in the high end of this range. Francis (1983) used a bioenergetics approach to calculate daily ration for Pacific whiting and arrived at somewhat lower values—between 0.71 and 1.09 percent body weight per day for whiting during their feeding season. Since adult whiting do not feed continuously throughout the year, Francis (1983) estimated the annualized average value for whiting consumption at 0.4-0.5 percent body weight per day using a bioenergetic approach.

Although this value seems low in comparison with other published values, it seems reasonable considering the seasonality of feeding in Pacific whiting. If Livingston's estimate of 2.5 percent body weight per day was annualized to account for nonfeeding periods, it would probably be about 1.2 percent body weight per day.

Francis (1983) calculated the differences in total annual consumption by the Pacific whiting population between unexploited and exploited conditions which would correspond to the time periods 1952-65 (unexploited) and 1966-77 (exploited). The average annual difference in the whiting population's total food consumption was estimated to be 412,000 t/year over its range from California to Vancouver, B.C. The pandalid shrimp fishery off the coast operates mainly in the Eureka-Columbia International North Pacific Fisheries Commission (INPFC) areas, and the difference that whiting exploitation could make in pandalid shrimp consumption by the whiting population can be calculated for these areas. According to Francis (1983), the total difference in average annual food consumption by whiting between the exploited and unexploited condition in these areas is about 258,000 t. Whiting food habit data in the same areas indicate that the diet of whiting >450 mm in length (about age 5+) consists of between 0.3 percent and 4.5 percent by weight of pandalid shrimp. About 54 percent of the whiting population is age 5+ in those areas, as estimated from age composition data in bottom and midwater trawl samples (Dark et al., 1980). Thus, the pandalid shrimp consumption by whiting in the Eureka-Columbia INPFC areas would decrease by between 417 t and 6,255 t when whiting are exploited. The average catch of pandalid shrimp increased from 1,800 t when whiting were unexploited (1952-65) to 12,000 t when whiting were exploited (1966-77). This increase, however, does not seem attributable to decreased predation by whiting; the average catch per unit effort of pandalid shrimp has not changed appreciably in the two periods (from 274 kg/h to 269 kg/h), and one would expect CPUE to increase if more shrimp were to become available to the fishery. An analysis of the history of the pandalid shrimp fishery reveals that total catch increased largely because the total effort in terms of vessels landing shrimp in Oregon increased from 45 boats in 1967 to 117 boats in 1976 (Pacific Fishery Management Council, 1980). Thus, there does not seem to be strong evidence pointing towards a large predator-prey interaction between whiting and pandalid shrimp.

Pacific Whiting: The Prey

Predation on Eggs and Larvae

Predation on fish eggs and larvae may be a major source of Pacific whiting mortality (Hunter, 1981). Eggs of the coastal stock are small (about 1 mm diameter) and are located mainly at the bottom of the mixed layer, at about 50 m depth. They have an extremely hard cuticle, which might make them invulnerable to some smaller grasping invertebrate predators and to some gelatinous zooplankton lacking penetrating nematocysts. In addition, whiting eggs are immobile and thus would not be vulnerable to ambush-type predators, due to the low probability of an encounter, or to nonvisual predators requiring tactile stimulation. Whiting eggs are vulnerable to raptorial or large filter feeding predators, and laboratory studies have demonstrated that amphipods, medusae, and other gelatinous zooplankton are efficient predators on whiting eggs. Euphausiids have been shown to eat anchovy eggs (Theilacker and Lasker, 1974) and are probably also able to eat whiting eggs. Filter feeding fishes may be predators on whiting eggs, as they have been shown to eat eggs of other species (Daan, 1976; Garrod and Harding, 1981; Hunter and Kimbrell, 1980).

Whiting larvae, like other gadids in general, are small (3 mm in length at hatching) and are feeble swimmers; consequently, they are vulnerable to many invertebrate predators (Bailey and Yen, 1983; Bailey, 1984). Larvae in the yolk-sac stage are the most vulnerable to predators, being extremely small and with undeveloped escape responses. Invertebrate predators on whiting larvae include predatory copepods, amphipods, euphausiids, and gelatinous zooplankton; but by the time larvae are about 5 mm in length they are probably invulnerable to many invertebrate predators. Larvae may also be vulnerable to predatory fishes, although as with eggs, little is known of this interaction.

Field examinations of the impact of predators on the survival of whiting eggs and larvae of the coastal stock are nonexistent. Bailey and Yen (1983) suggested that invertebrate predators may have a significant impact on survival of whiting larvae in Puget Sound. Many invertebrate predators in larval nursery areas had black guts, probably from ingesting pigmented whiting larvae. Furthermore, a decline in survival from egg to feeding stages of whiting was correlated with increased numbers of invertebrate predators.

Predation on Juveniles and Adults

Juvenile and adult whiting have been found in the stomachs of many predators, including dogfish, *Squalus* spp.; rays, *Raja* spp.; sablefish, *Anoplopoma fimbria*; lingcod, *Ophiodon elongatus*; arrowtooth flounder, *Atheresthes stomias*; rockfishes, *Sebastes* spp.; tunas, Scombridae; marine mammals, and birds. Predation on whiting by fishes may be limited to young of the year and 1-year-old whiting, while mammals may eat older animals. Due to the size stratification of whiting with latitude (Dark et al., 1980), few fish predators eat whiting in the northern part of their range, where whiting are generally >30 cm. Whiting are a common prey of fishes in the juvenile nursery area, off the California coast.

In the whiting's juvenile nursery

area, rockfish, genus *Sebastes*, are abundant predators. In a 1980-81 survey, whiting were found in about 350 of 5,000 stomachs, including bocaccio, *Sebastes paucispinis*; chilipepper, *S. goodei*; widow rockfish, *S. entomelas*; yellowtail rockfish, *S. flavidus*; and copper rockfish, *S. caurinus*[1]. Almost all whiting prey were young of the year (90-150 mm) fish. Off the Oregon-Washington coast, however, the stomachs of five rockfishes (yellowtail rockfish; splitnose rockfish, *S. diploproa*; canary rockfish, *S. pinniger*; darkblotched rockfish, *S. crameri*; and Pacific ocean perch, *S. alutus*, were examined and contained no whiting (Brodeur, 1982).

Scombrids are another potentially important group of whiting predators. Mackerels are reported to eat fish larvae and juveniles. Whiting occur fairly infrequently in the stomachs of tuna; they were found in 1, 2, and 6 percent, respectively, of the stomachs of albacore, *Thunnus alalunga*; bonito, *Sarda chiliensis*; and bluefin tuna, *T. thynnus* (Pinkas et al., 1971).

Pacific whiting have been found in the guts of several birds, most notably in the guts of the sooty shearwater, *Puffinus griseus* (Chew, 1984). In 37 gut samples from southern California in 1976-77, whiting otoliths were found in 51 percent of the samples. However, in 1979, no whiting were found in 154 birds sampled from Monterey Bay. Although the size frequency of whiting in guts was not available, other fish prey were in the 50-80 mm range, corresponding to young-of-the-year if whiting prey are a similar size. Sooty shearwaters may be important predators because during their seasonal migration northward they are the main bird biomass along the coast[2]. Whiting have also been found as a component (2-14 percent frequency of occurrence) in the food the western gull, *Larus occidentalis*, fed to its chicks from 1972 to 1977 (Hunt and Butler, 1980). The highest occurrence of whiting in the diet was in 1977, corresponding to the presence of the strong 1977 year class as young-of-the-year fish.

Marine mammal predators on whiting include the northern elephant seal, *Mirounga angustirostris*; northern fur seal, *Callorhinus ursinus*; California sea lion, *Zalophus californianus*; Pacific white-sided dolphin, *Lagenorhynchus obliquidens*; Dall porpoise, *Phocoenoides dalli*; killer whale, *Orcinus orca*; and sperm whale, *Physeter catodon*.

Whiting may be particularly important in the diet of California sea lions, occurring in 49 percent of scats examined from San Miguel Island, off southern California (Antonelis et al., In press). Almost all whiting otoliths were from 1-2 year old fish. By contrast, farther north off the Farallon Islands, whiting otoliths from scats and spewings were predominantly from 2-3 year old fish (Ainley et al., 1982). Seventy-eight percent of identifiable hard parts such as fish otoliths or shellfish beaks were whiting otoliths.

In its southern range, the northern fur seal may consume many whiting. In fur seals sampled from 1958 to 1968 off California, an average annual value of 25 percent of stomachs contained whiting. Farther north off the Washington coast, only 4 percent contained whiting, and off British Columbia, 1 percent contained whiting (Fiscus, 1979).

Several attempts have been made to estimate consumption of whiting by marine mammals. These estimates range from 8,600 t/year of whiting consumed by northern fur seals (Antonelis and Perez, In press) to 12,000, 185,000, and 3,400 t/year of whiting consumed by northern fur seal, California sea lions, and northern sea lions respectively (Bailey and Ainley, 1982). Table 2 shows estimates of pinniped consumption of whiting from data used in Laevastu's Probub ecosystem model (Laevastu and Larkins, 1981). These estimates are much higher than those of Antonelis and Perez, and range from a total of 134,300 t/year of whiting consumed by pinnipeds off Washington and Oregon to 152,300 t/year of whiting consumed off California. Consumption estimates are sensitive to values used for mammal population abundance and distribution, daily ration, and percent whiting in the diet. Since those studies were completed, Hawes (1983) found that in studies with captive animals, analysis of feeding habits based on mammal scats and spewings may be seriously biased. In controlled mammal feeding experiments, a high percentage of otoliths were not recovered, especially from mammals fed fish with small otoliths. Due to dissolution during digestion, fish otoliths were found to shrink; furthermore, squid beaks and large otoliths were frequently regurgitated rather than passed through the intestines. Because sacrificing mammals for their stomach contents is not desirable, Hawes suggests incorporating correction factors into consumption estimates to correct for these biases.

Summary of the Trophic Role of Pacific Whiting

Figure 6 depicts the changing array of whiting predators and prey throughout the whiting's life history stages. As whiting progress from larvae to adults, their prey choices switch from small items such as copepod eggs and copepods, to progressively larger items like euphausiids, shrimp, sand lance, eulachon, and herring. Similarly, whiting predators increase in size with the whiting's increasing size; from predatory zooplankton which consume whiting eggs and larvae, through fish which eat mostly whiting larvae and juveniles, to larger

Table 2.—Probub model estimated pinniped consumption of Pacific whiting in t/year, Washington-Oregon and California.

Pinniped	Washington-Oregon	California
Northern fur seals	53,700	58,900
Northern sea lions	41,300	31,300
California sea lions	9,400	19,500
Elephant seals	29,900	42,600
Total	134,300	152,300

[1]T. Echeverria, Tiburon Laboratory, Southwest Fish. Cent. NMFS, NOAA, Tiburon, Calif. Pers. commun.

[2]G. Hunt, Univ. Calif. Irvine, Irvine, Calif. Pers. commun.

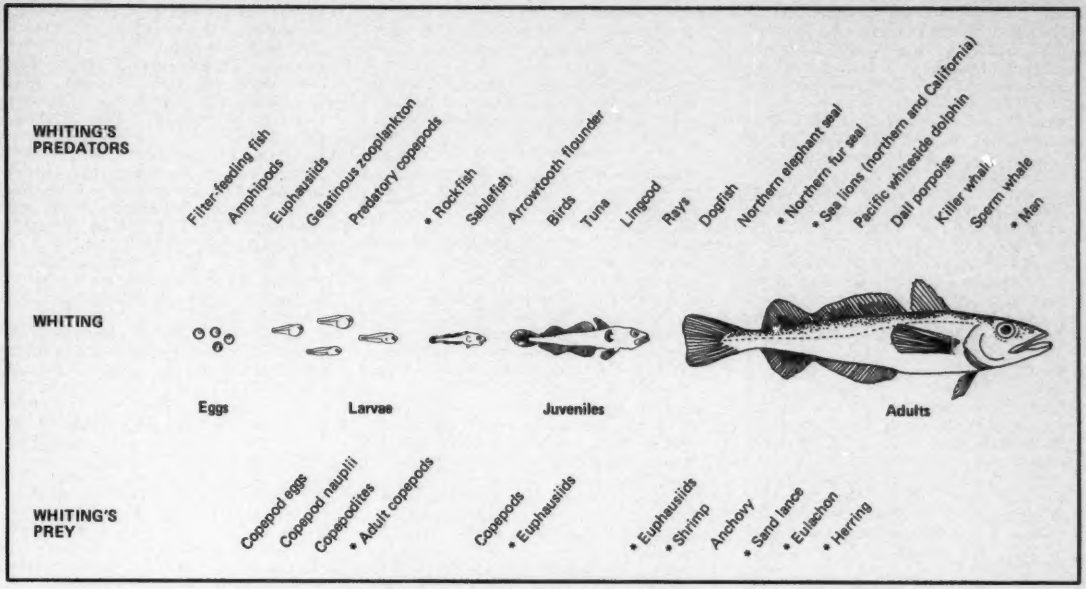

Figure 6.—Representation of Pacific whiting's predators and prey in various life history stages of whiting. (Asterisk indicates major predators or prey.)

predators such as large fish, dogfish, and mammals which prey mostly on older juveniles and adult whiting. Also evident (Fig. 6) is the number of commercially important or protected species linked to whiting: Shrimp, anchovy, herring, rockfish, and marine mammals.

From a management point of view, it is important to identify and quantify the links between one managed species and another. Here we have identified the major links between whiting and its important predators and prey. Some quantification of the links has been performed using daily ration estimates and stomach content analysis results to estimate the rate of biomass flow between species. In particular, the link between whiting and one of its commercially important prey items, pandalid shrimp, has been calculated and compared with historical trends in the pandalid shrimp fishery. Estimating biomass flow in the other links requires accurate daily ration estimates, seasonal and size-related definition of stomach contents, and predator population estimates. Due to inaccuracies of some of these parameters, it seems somewhat premature to place a great deal of faith in the resulting biomass flow estimates. In particular, refinement of daily ration estimates for whiting and mammals to take into account differential digestion of various prey types would be a logical step, as would better methods to evaluate stomach contents (such as an unbiased mammal stomach content analysis method). When these are obtained, a more reliable management perspective may follow.

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Biology and Fishery of Pacific Whiting, *Merluccius productus*, in the Strait of Georgia

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ABSTRACT—*Pacific whiting,* Merluccius productus, *in the Strait of Georgia constitute a distinct stock. Spawning occurs from March to May in the south central Strait. There is marked vertical segregation of the sexes during spawning. Active spawning occurs below 220 m. Post-spawning fish aggregate in the shallow waters (50-100 m) and are found in association with a dense plankton layer. By fall, most whiting have migrated out of the open Strait. In early winter, adults reappear and migrate into the south central Strait in preparation for spawning. Juvenile Pacific whiting were common but segregated from the adult concentrations. Eggs and larvae were abundant in the central Strait from March to May at depths of 100-300 m. By June, catches of larval whiting had decreased.*

Whiting were aged using broken and burnt otoliths and the technique validated to age 12 by following the strong 1970 year class. Whiting show a constant, relatively rapid growth to age 4, followed by little or no growth. The oldest fish captured was 20 years. Length at 50 percent maturity was 33 cm for males and 37 cm for females. Absolute fecundities were determined, and the relationship for all egg diameters from 180 to 780 mm was $F = (5.501 \times 10^{-1})L^{3.3896}$. *Also discussed is the presence of large numbers of yolked oocytes remaining in the ovary after spawning.*

Pacific whiting feed mainly on pelagic and semipelagic animals. Whiting may be an important predator on herring in the Strait with about 15 percent feeding exclusively on herring during April and May. Salmon have never been identified in whiting stomachs.

Pacific whiting is the most abundant resident fish stock in the Strait, with estimated stock size ranging from 85,000 to 130,000 t. The abundance of whiting appears to have increased substantially since 1970 because of a succession of strong year classes. Total annual mortality (A) is estimated to be 0.15-0.25. The Pacific whiting fishery in the Strait of Georgia is recent, ranging from 508 t in 1979 to 2,378 t in 1982. Preliminary MSY estimates range from 10,000 to 15,000 t. The resource represents a potentially attractive fishery. The absence of the myxosporean parasite Kudoa paniformis *and the proximity to land-based processing have increased interest in both the food fish and roe fisheries.*

Introduction

Discovery of large midwater concentrations of Pacific whiting, *Merluccius productus*, in British Columbia's Strait of Georgia was made in 1974 (Westrheim, 1974), and studies of biology, distribution, and abundance commenced in 1975 (Beamish et al., 1976a-e, 1978a, b, 1982; McFarlane et al., 1983; Thompson and McFarlane, 1982). Pacific whiting in the Strait of Georgia are now recognized as the most abundant resident fish.

The developing Canadian fishery for offshore whiting provided a stimulus for exploitation of resident stocks in the Strait of Georgia. Even though Pacific whiting in the Strait of Georgia are smaller, they are free of the parasite *Kudoa paniformis* which is responsible for the rapid degradation of the flesh of offshore whiting (Kabata and Whitaker, 1981). The absence of this parasite and the proximity of the stocks to land-based processing make this a potentially attractive fishery. In addition, there is a potential for harvesting roe[1] since large concentrations of spawning fish are available.

This report summarizes current knowledge of the distribution, abundance, biology, and management of Pacific whiting in the Strait of Georgia by the Canadian Department of Fisheries and Oceans between 1974 and 1981 from commercial trawl catch data collected by vessel observers and port samplers. Survey and sampling methods are described in publications cited in the text. Commercial catch data were taken from Department of Fisheries and Oceans annual reports (Smith, 1981) and from computer files developed from sales slips and interviews with the crews at landing.

[1]H. Tsuyuki, Department of Fisheries and Oceans, Technology Laboratory, University of British Columbia, Vancouver, B.C., Canada. Personal commun., Jan. 1983.

Stock Delineation

Pacific whiting in the Strait of Georgia constitute a distinct population and are much smaller than offshore whiting (Beamish et al., 1982). The shape and size of the otolith and the pattern of annuli formation are distinctive (Fig. 1, 2). Otoliths from the offshore whiting are more elongate and in section are less concave. The strong year classes present in the offshore whiting (Beamish, 1981) are not synchronous with those of the Strait of Georgia whiting. In addition, the absence of the myxosporean parasite. *K. paniformis* (Kabata and Whitaker, 1981) clearly indicates the absence of interchange with the offshore population.

Within the Strait of Georgia there are discrete whiting stocks. For example, a small stock of larger whiting has

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been found in spawning condition 4-6 months prior to main spawning (Beamish et al., 1976d). A stock of actively spawning whiting has been found northwest of Texada Island, near Montgomery Bank (Fig. 3). Small groups of whiting have been observed in other areas such as mainland inlets, and it is suspected that these constitute distinct local stocks.

Distribution

Adult

Pacific whiting spawn from March to May in the deeper water of the south central Strait (Fig. 4). Biomass surveys indicate that about 80 percent of adult Pacific whiting are present in this area at this time. The major spawning aggregation is located south and west of Halibut Bank at depths from 150 to 350 m (Fig. 5). During peak spawning, about 35 percent of the fish are concentrated in this aggregation (Cass et al., 1978; Thompson and McFarlane, 1982).

Two distinct midwater layers of whiting are present in the Strait during spawning (Cass et al., 1978; Thompson and McFarlane, 1982). The shallower layer is present at about 50-120 m (and appears as a light scattering layer over the spawning aggregation (Fig. 5a) and discrete schools elsewhere (Fig. 5b). The deeper layer exhibits a continuous distribution of varying densities from about 150 to 320 m.

During March and April, the percentage of prespawning fish remains constant, with females occupying the shallow layer (75 percent) and males occupying the upper portion of the deep concentration. At this time there is a marked increase of actively spawning males and females in the lower portion of the deeper concentration. The greatest percentage of actively spawning fish is below 220 m. By late April-early May, 85 percent of the males and females have completed spawning and are aggregating in shallow layer (50-80 m) on the west side of the Strait, along Vancouver Island (Fig. 6). During the day, these aggregations are found in association with a dense plankton layer (Fig. 7) common throughout the Strait at this time of year and form discrete dense schools (Fig. 8a). Below these schools the density is greatly reduced, but distribution is continuous. At night the dense schools disperse and whiting

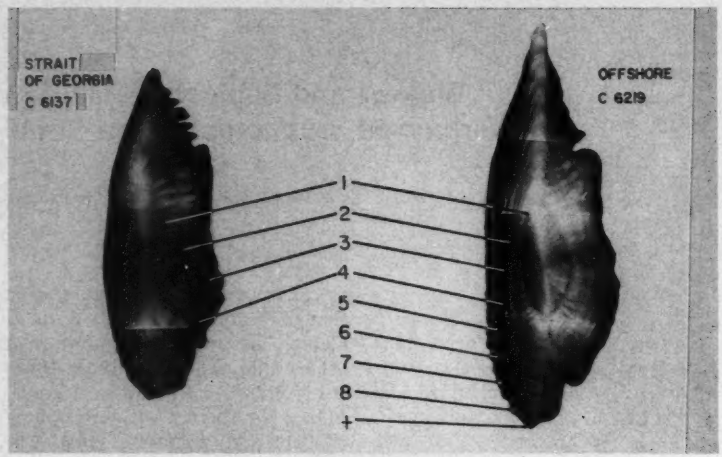


Figure 1.—Surface view of otolith from Strait of Georgia and "offshore" Pacific whiting showing the difference in size and shape of the otoliths from the two stocks. Both fish were age 8+ using the "broken and burnt" method (see Figure 2).

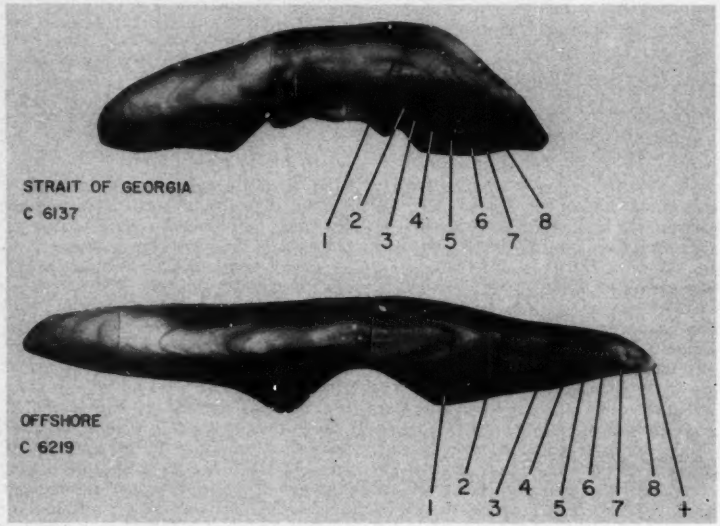


Figure 2.—Broken and burnt otolith sections from Strait of Georgia and "offshore" Pacific whiting showing the difference in the growth of the otolith in cross-section and in the pattern of annuli formation.

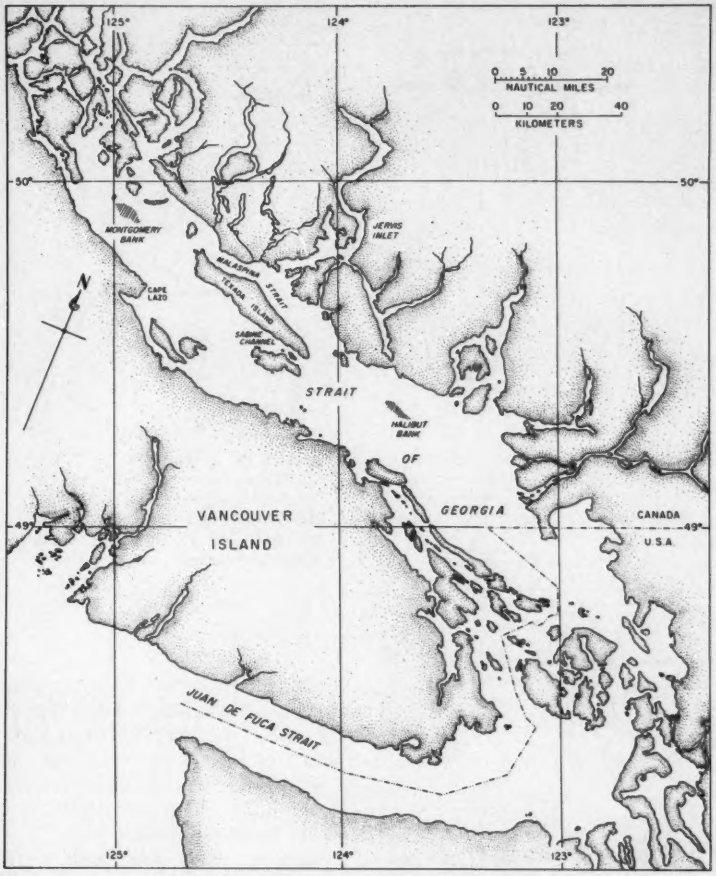


Figure 3.—The Strait of Georgia and its prominent banks.

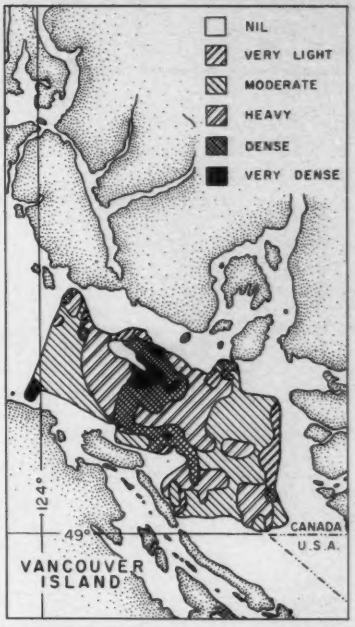


Figure 4.—Spawning distribution of Pacific whiting in the Strait of Georgia as represented by echogram and catch estimates (March).

migrate toward the surface (Fig. 8b). By fall, whiting aggregations have moved north and schools become dispersed (Fig. 9a). In late fall, few whiting are found in the Strait and it appears that they have migrated into the Johnstone Strait area (Fig. 9b). In early winter, aggregations reappear and adult whiting begin to migrate down Malaspina Strait and Sabine Channel toward the central Strait in preparation for spawning (Fig. 10).

Juvenile

Juvenile Pacific whiting aged 1-3 years are distributed throughout the Strait of Georgia. During February 1981 (McFarlane et al., 1982b; 1983), age 1+ whiting were captured throughout the open Strait from the Apex to Montgomery Bank in the northern Strait. Previous studies (Beamish et al., 1978a; Cass et al., 1978; McFarlane et al., 1983) have reported Strait-wide distribution of age 1+ whiting with relatively large catches in Malaspina Strait and Jervis Inlet. Age 1+ whiting were found throughout the water column but the majority were caught in sets where the average net depth was less than 200 m. Whiting, estimated to be age 2+ and age 3+ from length-frequency analysis, have been captured at all depths throughout the Strait of Georgia. Comparison of size composition of whiting by depth shows no obvious spatial separation (Beamish et al., 1978a; McFarlane et al., 1982a, b, 1983); however, large numbers of juveniles were generally captured in areas where adult catches were small, particularly away from spawning concentrations in the central Strait. Some young-of-the-year whiting moved into the shallower inshore waters, such as the Gulf Islands and remained there for 2 years (Beamish et al., 1978b). During their third year of life (age 2+), they moved out of this area and appeared to concentrate in the south central Strait.

Ichthyoplankton

Egg and larval plankton surveys carried out in the Strait of Georgia in

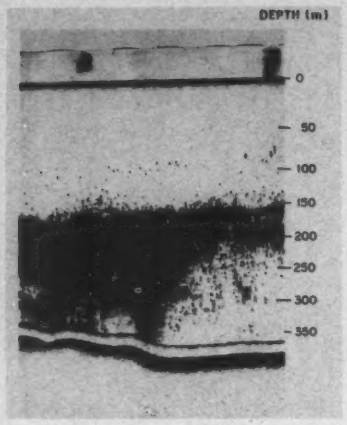


Figure 5a.—Echogram representing the spawning aggregation in the south central Strait during March.

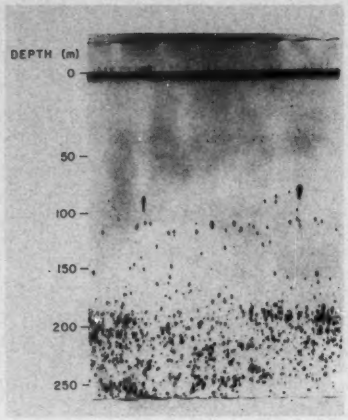


Figure 5b.—Echogram representing two distinct midwater layers common throughout the south-central Strait just prior to spawning.

Figure 6.—Distribution of post-spawning Pacific whiting in the Strait of Georgia (April-May). Note the heavier concentrations found on the west side of the Strait along Vancouver Island.

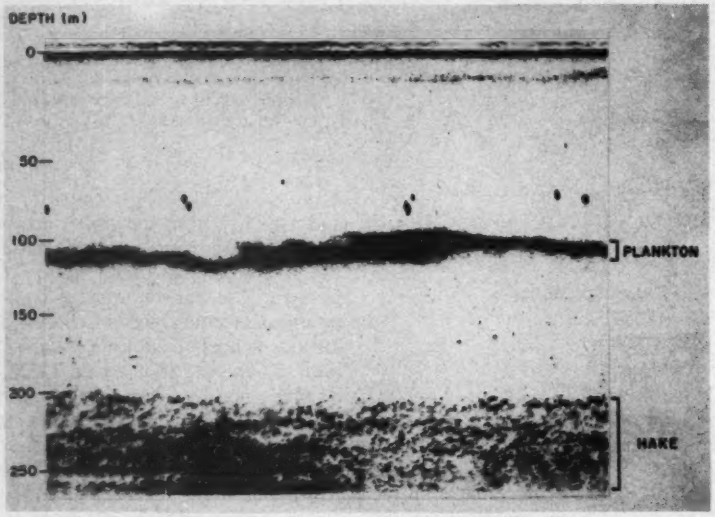


Figure 7.—Echogram showing discrete schools of Pacific whiting in association with dense plankton layer during April-May.

1979, 1980, and 1981 suggested a distribution of spawning whiting[2] similar to that described from trawl surveys. Eggs were common throughout the south central Strait and were densest off Halibut Bank. A smaller dense concentration was present northwest of Texada Island, near Montgomery Bank. Whiting eggs were found at depths of 100-300 m in the open Strait from March to May. Maximum density occurred at 170-220 m in early April. Larvae were found at 200-250 m and at shallower depths as they developed.

Surveys with Isaacs-Kidd and plankton nets carried out from 1961 to 1973 (Barraclough, 1967a, b, c; Barraclough and Fulton, 1967, 1968; Barraclough et al., 1968) indicated that whiting larvae were rare in the surface waters of the open Strait. Mason (footnote 2) found whiting larvae as deep as 300 m but the highest density was 200-250 m during April. Whiting larvae were abundant throughout the midwater during April-May, but by June catches of larval whiting had decreased substantially.

Age Growth and Maturity

Initially, age was estimated from the exterior surface of the otolith. However, it was soon evident that the annuli on the periphery of otoliths of older fishes were difficult to distinguish. Examinations of sections

[2]J. C. Mason, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada V9R 5K6. Personal commun., Nov. 1982.

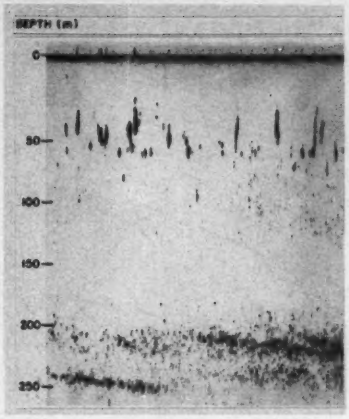


Figure 8a.—Echogram showing concentrations of Pacific whiting during daylight hours. Note discrete schools of whiting in shallow layer.

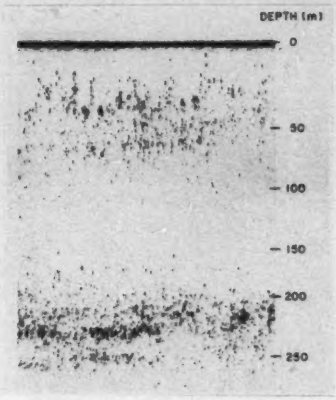


Figure 8b.—Echogram showing concentrations of Pacific whiting during night. Shallow layer schools have dispersed throughout the upper 100 m.

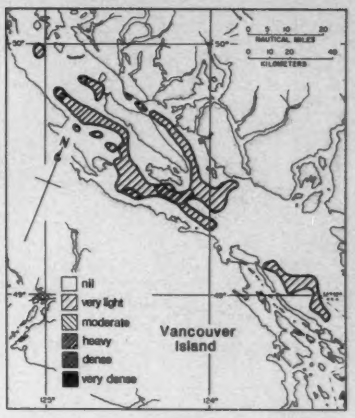


Figure 9a.—Distribution of Pacific whiting in the Strait of Georgia during fall (September).

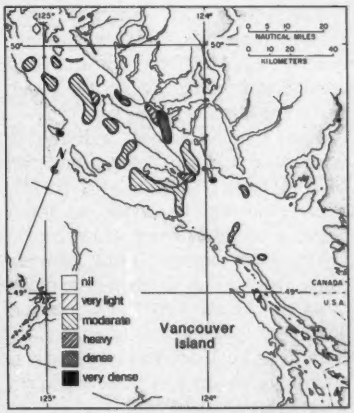


Figure 9b.—Distribution of Pacific whiting in the Strait of Georgia during late fall (December). Note the absence of whiting in the Strait at this time.

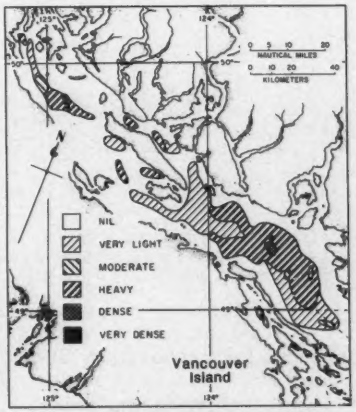


Figure 10.—Distribution of Pacific whiting in the Strait of Georgia just prior to spawning (February).

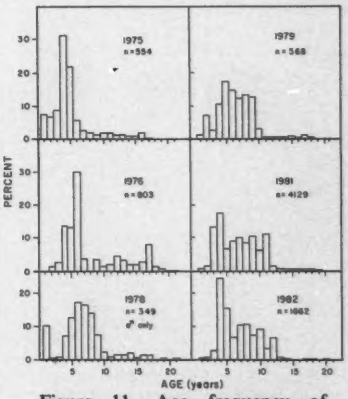


Figure 11.—Age frequency of Pacific whiting in the Strait of Georgia (1975-1982) showing the persistence of the strong 1970 year-class and the apparent increase in abundance of strong year-classes compared to the 1960's.

of otoliths (Beamish, 1979) indicated that annuli could be more readily identified. At present, otoliths are broken through the nucleus and burned (Chilton and Beamish, 1982) and sectioning is used only for otoliths that are very dificult to determine.

The ages estimated from the sectioning or broken and burnt methods have been validated for ages up to 3 years by comparison with length frequencies. Whiting aged 1, 2, and 3 years had modal lengths corresponding to similar modes in the length frequency at 11, 23, and 33 cm (Beamish et al., 1978a; Cass et al., 1978; McFarlane et al., 1982a; 1983). The 1970 year class in the Strait of Georgia has been identified each year since 1975 (Fig. 11), indicating that the zone identified as an annulus does

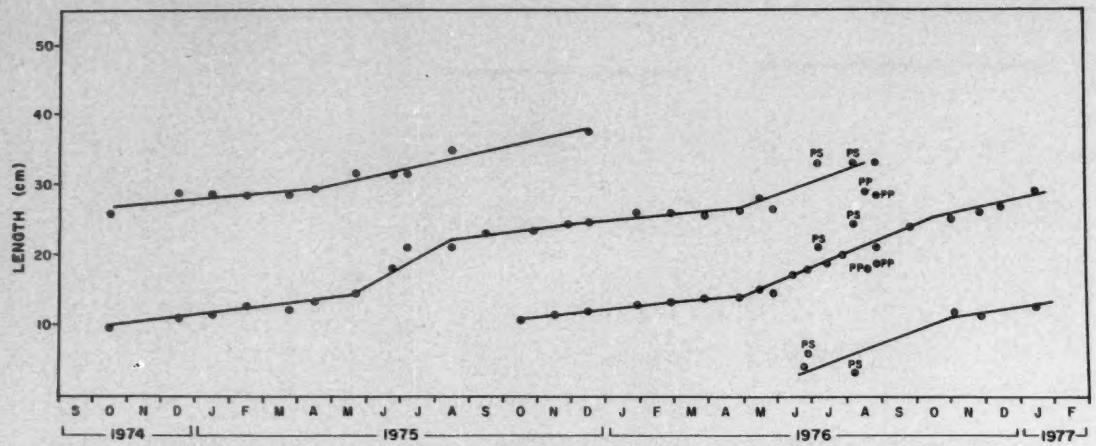


Figure 12.—Comparison of mean fork lengths, by year-class, of juvenile (0-3 years) Pacific whiting, 1974-77. Samples collected from Stuart Channel in Gulf Islands area of the Strait. (PS = purse seine; PP = samples from Porlier Pass).

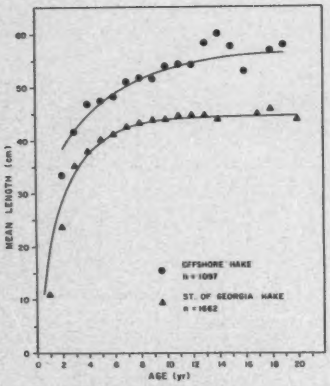


Figure 13.—Mean lengths at age from Strait of Georgia and "offshore" Pacific whiting. Solid lines derived from the von Bertalanffy growth equation with parameters of t_0 = -0.173, K = 0.457, L = 44.5 cm and t_0 = -3.043, K = 0.233, L = 56.9 cm for Strait of Georgia and "offshore" Pacific whiting, respectively.

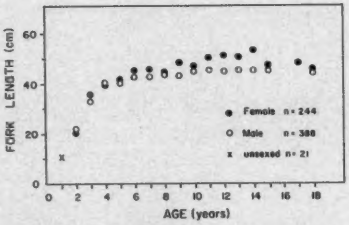


Figure 14.—Mean lengths at age for male and female Pacific whiting in the Strait of Georgia.

form once a year at least up until the age of 12.

Growth of juveniles (age 1+ and 2+) occurs mainly during May-November (Fig. 12). The pattern of annual growth throughout the year during the study period (1975-77) was similar.

Pacific whiting in the Strait of Georgia grow rapidly up to the age of 4, but at a slower rate than shown by the "offshore" whiting (Fig. 13). Population growth curves for males and females combined show a similar constant, relatively rapid, growth to age 4 and substantially slower growth thereafter. Male and female whiting (Fig. 14) show similar annual growth up to age 4 or 5, after which mean lengths for females are significantly larger (t-test $P \geq 0.05$). Mature males average 2-3 cm smaller than mature females. Both males and females continue to live for long periods during which little growth occurs.

The oldest fish was 20 years (McFarlane et al., 1983) but 83 percent of the fish from research and commercial catches during 1981 were in the range of 4-11 years.

The catch curves indicate a substantial increase in the abundance of year classes since 1970 (Fig. 15). The reason for this increase in abundance is currently being investigated.

Most (95 percent) adult whiting range from 40 to 50 cm with a mode at 44 cm. Modal length is 44 cm and 46 cm for males and females, respectively. The largest female sampled was 80 cm; however, less than 5 percent were larger than 50 cm.

The length-weight relationship is exponential (Fig. 16a, b). Estimates are given in Table 1. These estimates reflect prespawning and postspawning differences. McFarlane et al. (1983) found that growth in weight is seasonal and that during spawning adult whiting lose between 15 and 20 percent of their body weight.

The mean lengths (cm) of Pacific whiting at 50 percent maturity were calculated by probit analysis following the technique of Leslie et al. (1945) as described in Beacham and Nepszy (1980). Length at 50 percent maturity was 33 cm for males and 37

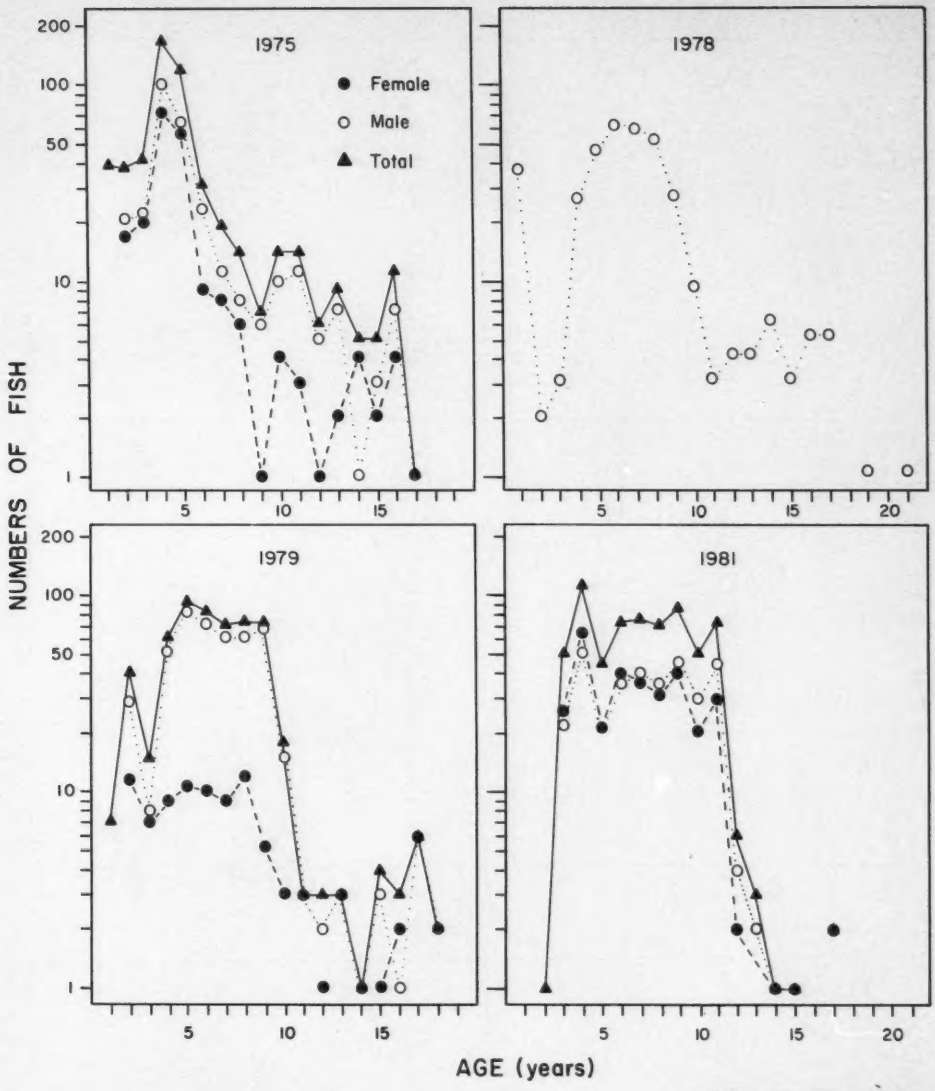


Figure 15.—Comparison of catch curves for Pacific whiting in the Strait of Georgia from 1975, 1978, 1979, and 1981, showing the progress of strong year-classes through the fishery and the apparent increase in abundance of strong year-classes compared to the 1960's.

Table 1.—Summary of Pacific whiting length-weight relationship values estimated using geometric regressions ($W = aL^b$).

Sampling period	Male				Female				Total		
	n	a	b	r	n	a	b	r	n	a	b
20 Feb.-3 Mar.	160	0.0155	2.7412		219	0.0056	3.029		379	0.0065	2.9969
24 Apr.-2 May	142	0.1406	2.1103	0.88	143	0.0619	2.337	0.83	326	0.0074	2.8923
3 July	137	1.0882	1.5712	0.83	99	0.2586	1.9693	0.91	237	0.5134	1.7791
Means (weighted)			2.172				2.5867				2.6543
Total	439				461				942		

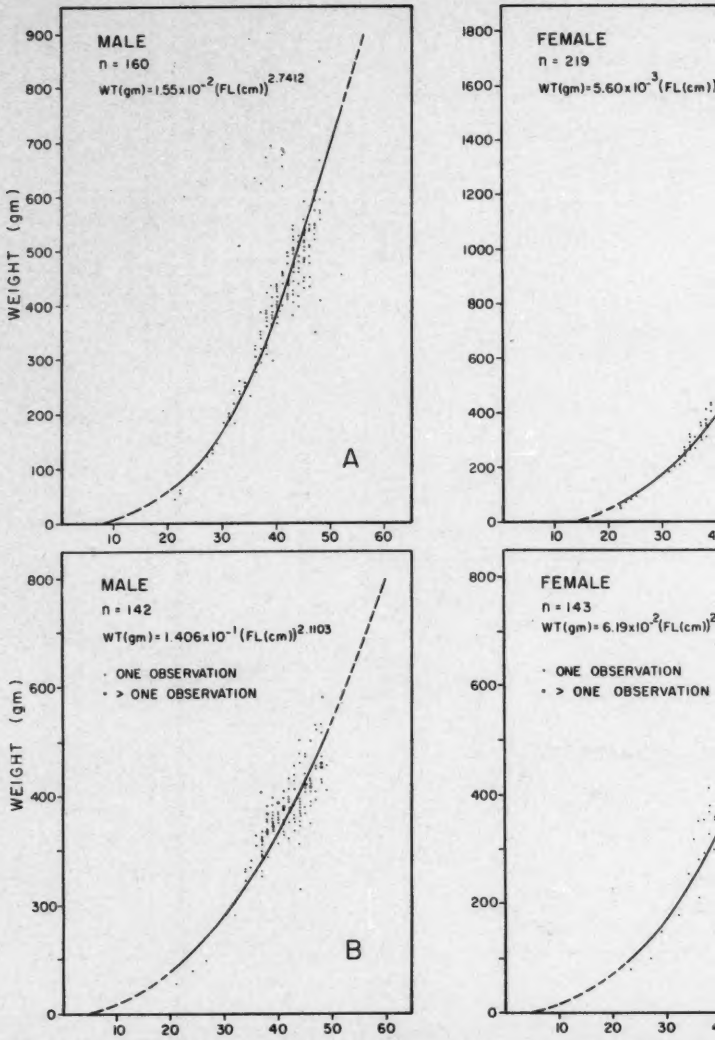
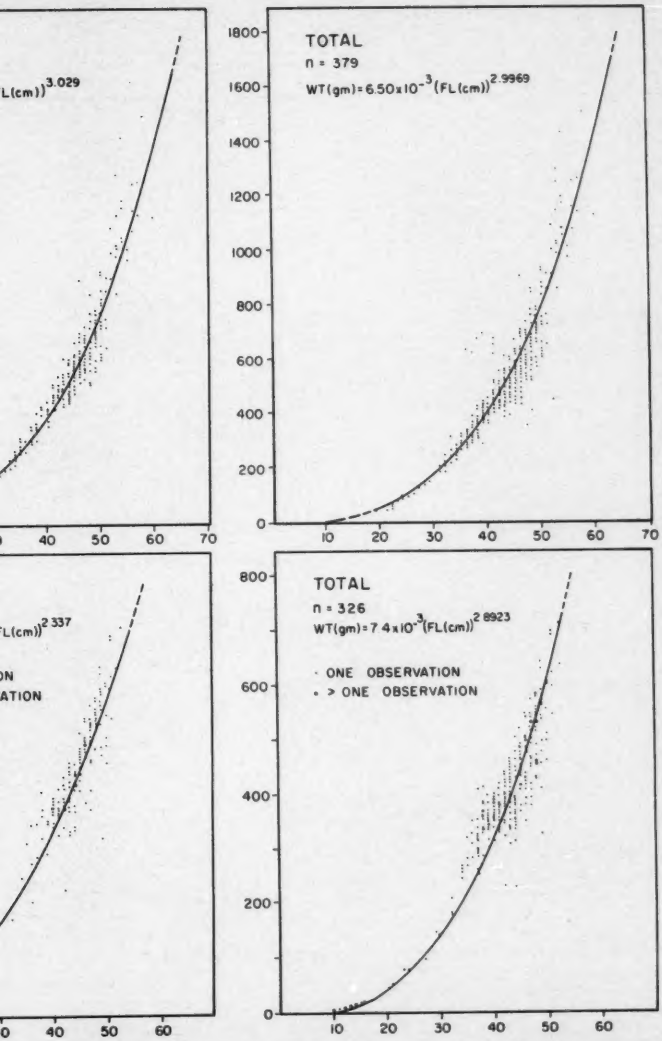


Figure 16a.—Length-weight relationships for Pacific whiting in the south-central Str



ral Strait of Georgia. A, 20 February-3 March 1981. B, 24 April- 2 May 1981.

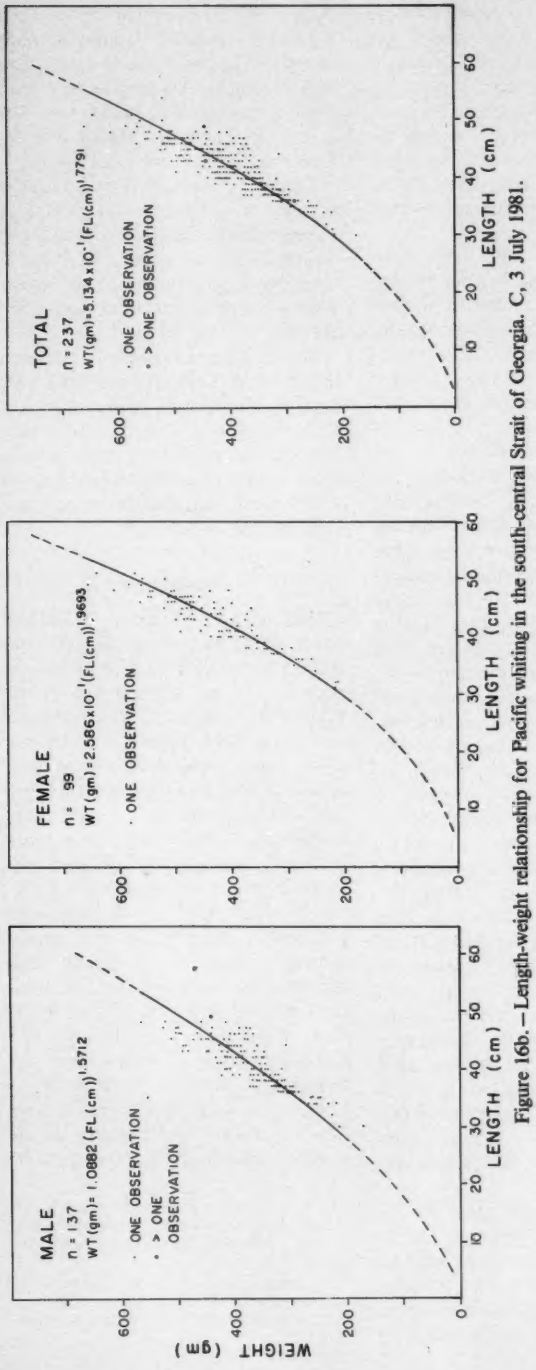


Figure 16b.—Length-weight relationship for Pacific whiting in the south-central Strait of Georgia. C, 3 July 1981.

cm for females, indicating that the year preceding first spawning is a period during which many of the recruiting year classes appear isolated from adults and other juveniles. By age 4, 100 percent of males and females are mature.

Fecundity and Egg Development

A histological study of Pacific whiting ovaries (Foucher and Beamish, 1980) indicated that multiple size modes of oocytes were present. Oocytes in the smallest mode (50-150 mm) contained no yolk and represent the reserve stock from which, each year, a proportion proceeds with further growth and maturation. Relatively large numbers of small- and large-yolked oocytes remained in the ovaries and were resorbed so that a second spawning did not occur. Nikolskii (1965) defined fecundity as "the number of eggs (oocytes) for the generation of that year present in the ovaries," i.e. the number that should be laid in that year. The occurrence of large, yolked oocytes remaining in the ovaries indicates that the assumptions used when making fecundity measurements must be clearly identified and that fecundity should be defined as the number of oocytes that are actually released to be fertilized (viable oocytes). It may be that an increased commercial fishery in the Strait would reduce stock size, resulting in an increase in the production of viable oocytes.

Absolute fecundities were determined for ripening whiting in the Strait of Georgia in February 1981. Predictive least squares linear regression of log fecundity (F) on log fork length (L), transformed to the exponential relationship, produced the following preliminary relationship from each egg diameter category.

Egg dia. (μm)	Geometric equation (Power curve)		Correlation r^2(%)
40-180	$F=(6.92\times10^{-2})$	$L^{3.9766}$	88
181-380	$F=(4.46\times10^{-2})$	$L^{3.7097}$	86
381-580	$F=(2.08\times10^{-1})$	$L^{3.4174}$	71
581-780	$F=(8.00\times10^{-4})$	$L^{4.647}$	65
181-780	$F=(5.50\times10^{-1})$	$L^{3.3896}$	81

These relationships indicate that the relative potential fecundity per unit weight increases with size (and presumably age) of the fish. However, as it is difficult to differentiate between viable and nonviable oocytes in each size category, current studies of whiting fecundity include oocyte counts and a histological examination of spent and recovering ovaries to examine this relationship. It is apparent that the fishery must be monitored closely to determine the reproductive response to increased exploitation.

Feeding and Predation

There has been no comprehensive study of the diet of Pacific whiting in the Strait of Georgia. Food observations have been taken incidental to other studies (Beamish et al., 1978a, 1982; Cass et al., 1978, 1980; McFarlane et al., 1982b, 1983).

The diet of adult Pacific whiting in the Strait is composed mainly of pelagic and semipelagic animals. Fish captured in the dense aggregations fed primarily on euphausiids (60-82 percent of the diet by volume) throughout the year. Other invertebrates, comprising 1-5 percent of the stomach contents, were amphipods (*Euprimo abyssolis*, *Parathemisto pacifica*, *Cyphocaris* sp., and *Calliopius* sp.); glass shrimp, *Pasaphia pacifica*, and squids. Also present were small, off-bottom fishes such as Pacific herring, *Clupea harengus pallasi*; *Bathylagus* sp.; eulachon, *Thaleichthys pacificus*; unidentified myctophids, and juvenile whiting.

Pacific whiting not associated with the dense aggregations fed more heavily on fish, primarily *Bathylagus* sp. Glass shrimp was also a major prey species of the nonschooling whiting.

Pacific whiting fed throughout the year, but the proportion of empty stomachs was larger and mean stomach content lower in winter samples than summer (Beamish et al., 1976b, 1982; Weir et al., 1978; Cass et al., 1978; McFarlane et al., 1982b, 1983). Adults feed very little during spawning. After spawning, dense feeding aggregations form at depths of 40-100 m in association with the heavy plankton layer. Euphausiids remain an important component of the whiting diet; however, during this time herring become the dominant fish species in the diet, comprising between 15 and 20 percent in May and 9 percent in June. There was some indication of seasonality and size selectivity of prey; however, data are insufficient to quantify those observations.

Juvenile whiting have been identified in adult stomachs, but the extent of cannibalism is unknown. One survey (Shaw et al., 1983) carried out in March-April 1976 identified young-of-the-year whiting as the dominant food item of adults in the south-central Strait.

Dominant fish predators in the Strait of Georgia are Pacific whiting; walleye pollock, *Theragra chalcogramma*; rockfish, *Sebastes* spp., Pacific salmon, *Onchorhynchus* spp., Pacific herring; and, to some extent, juvenile sablefish, *Anoplopoma fimbria*. Although quantitative studies of interactions have not been made, predation and competition for food may have an effect on developing and established fisheries. Observations made during a series of cruises in 1981 (McFarlane et al., 1983) indicated that about 15 percent of whiting were feeding exclusively on herring. It was estimated that more than 50 percent of the whiting stock was present in this area during this time (April, May) and may have consumed 4,000-8,000 metric tons (t) of herring. While this estimate is preliminary, it does indicate that whiting predation on herring could be important, particularly considering that the annual herring landings have ranged from 10,000 to 18,000 t. It is important to note that of the 10,000 whiting examined for stomach contents since 1975, not one salmon has ever been identified.

In the Strait of Georgia, Pacific whiting are preyed upon by spiny dogfish, *Squalus acanthias*; walleye pollock; and Pacific cod, *Gadus macrocephalus*, and, in the inshore waters, juveniles are preyed upon by lingcod, *Ophiodon elongatus*, and rockfish species. Whiting eggs at all stages of development have been found in pollock stomachs and, though rarely, whiting. Marine mammal predators include the fur seal, *Callorhinus ursinus*; California sea lion, *Zalophus californianus*; and the Steller sea lion, *Eumetopias jubatus*[3].

Lamprey, *Lampetra* sp., attacks account for some natural mortality. In sets made in the south central Strait during 1981, <1 percent of the fish bore lamprey wounds. This agrees with previous reports (Beamish et al., 1976d).

As the dominant resident species in the Strait of Georgia, one would expect Pacific whiting to be important both as predator and prey for a variety of other animals at some stage in their life history. The importance of these interactions remains to be clearly identified.

Abundance

Preliminary estimates of abundance of adult whiting ranged from 100,000 to 200,000 t based on hydroacoustic surveys carried out in the mid-1970's[4] and ichthyoplankton surveys in 1979 (footnote 2). During 1981, three methods (swept-volume trawl surveys, hydroacoustic surveys, and ichthyoplankton surveys) were employed to determine the abundance of Pacific whiting. Surveys were carried out in the entire Strait, but emphasis was placed on the spawning population present in the south-central portion of the Strait. The results of the study will form the basis for future management of whiting. At this time the results of the ichthyoplankton surveys are not available; however, preliminary estimates from the swept-volume trawl surveys and hydroacoustic surveys range from 85,000 to 130,000

[3]M. Bigg, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada V9R 5K6. Personal commun., Jan. 1983.

[4]R. Kieser, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada V9R 5K6. Personal commun., Nov. 1982.

t (Thompson and McFarlane, 1982) and 40,000 to 150,000 t (Kieser, 1983), respectively. These estimates are lower than the earlier hydroacoustic estimates.

It appears that since 1970 there has been a period of increased abundance of whiting because of a succession of strong year-classes relative to the 1960's (Fig. 15). The reason for the relative success or abundance remains to be identified. It also remains to be shown whether there has been a periodicity in whiting abundance.

Mortality

Total annual mortality (A) and total instantaneous mortality (Z) have been estimated from the slope of the right-hand limb of the catch curves (Jackson, 1939). The slope of the catch curves (Fig. 15) indicates that annual recruitment is not constant and that at least one of the assumptions required by the method was violated. Early studies indicated the presence of a plateau in the vicinity of ages 5-7 (Beamish et al., 1976a. 1978a; Thompson and Beamish, 1979). Depending on where on the catch curve fish were considered to have been recruited, mortality estimates of A = 0.21-0.74 were obtained, corresponding to instantaneous mortality rates of Z = 0.24-1.35.

Recent studies (Beamish et al., 1982; McFarlane et al., 1982a) have indicated that strong year classes are an important component of this population. Comparing the change in relative abundance of strong and weak year classes (McFarlane et al., 1983), using simple linear regression (Ricker, 1975), produced total annual mortality estimates of A=0.15-0.25 and corresponding to instantaneous mortality rates of Z=0.16-0.29. The lower estimates were determined for the weak 1967 year class and may be indicative of differential mortality rates between year classes or of year-specific mortality rates. Several consecutive years of age samples will be required to calculate accurate age, sex, and year-class mortality rates.

Management

The Pacific whiting fishery in the Strait of Georgia was not initiated until 1979; therefore, no historical data base is available with which to study possible effects of the fishery on the stocks. Catches during 1979 and 1980 were small, 516 t and 508 t, respectively. However, 2,400 t were landed in 1981, 2,824 t in 1982, and 3,111 t in 1983. As interest in the fishery increases and potential markets are explored, it is anticipated that this fishery will increase substantially over the next decade. The initial management approach was to calculate theoretical maximum sustainable yields (MSY), utilizing estimates of unexploited biomass (Bo) from hydroacoustic and swept-volume surveys during the mid-1970's as well as estimates of instantaneous natural mortality rates (M) (0.45-0.63).

The Gulland (1970) formula, $MSY = 0.5(M)(Bo)$, produced estimates ranging from 11,000 to 38,000 t. As these were preliminary parameter estimates, it was recommended that the total allowable catch not exceed 10,000 t until a reassessment of abundance estimates and other biological parameters was undertaken (Ketchen, 1980; Westrheim, 1980).

Using recent estimates of abundance (60,000-130,000 t) and mortality (0.19-0.29), the range in MSY is 6,000-19,000 t. Assuming abundance is near the midpoint of the estimates (100,000 t) obtained from the recent swept-volume midwater trawl, hydroacoustic, and ichthyoplankton surveys, and that mortality is in the range of estimates taken using changes in relative abundance of good year classes (0.19-0.29), then MSY is 10,000-15,000 t.

Estimates of MSY presented here may not represent the long-term average if there are large cycles in population size. Since the response of the stock to exploitation in terms of growth, survival, or reproductive potential cannot be assessed at this time, a conservative management strategy should be adopted until the combined effects of recruitment fluctuations and fishing are determined. Because female whiting produce a number of nonviable eggs that are resorbed, it is possible that a fishery will reduce the virgin stock which may result in increased fecundity. This increase in egg production per adult could conceivably result in increased yield.

Processing and Markets

Offshore Pacific whiting contain two myxosporean parasites. One of these parasites has recently been identified as a new species, *Kudoa paniformis* (Kabata and Whitaker, 1981), and shown to be responsible for the rapid degradation of the flesh (Tsuyuki et al., 1982). In addition, this parasite can induce a tissue response that results in the concentration of melanin which causes unsightly blotches in the flesh. In the Strait of Georgia, *K. paniformis* is absent and whiting flesh has a much better storage life (Tsuyuki et al., 1982). Whiting properly stored aboard the fishing vessel can be kept for up to 5 days. Thus, despite the smaller size, the better quality flesh makes this population an attractive fishery.

To date, most whiting have been processed as fillet blocks for institutional use. The white, mild-tasting, flaky flesh makes it a desirable substitute for cod. The fillet block product appears to have the most potential, particularly in the fast-food industry.

Recently, interest has been increasing in both headed and gutted and cured (salted) whiting. The demand is high for these types of products and the export potential appears good. Inquiries have also been received on the feasibility of using whiting for surimi. In addition, whiting roe harvested during February and early March exhibits the characteristics associated with good quality pollock roe (footnote 1).

Acknowledgments

Many people have participated in various parts of this study and we appreciate their support and coopera-

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Puget Sound Pacific Whiting, *Merluccius productus*, Resource and Industry: An Overview

MARK PEDERSEN

Introduction

There may be several aggregations of Pacific whiting, *Merluccius productus*, in Puget Sound, Wash., but only one currently supports a commercial fishery. This is the central Puget Sound population, which spawns locally in Port Susan (Fig. 1). It is distinct from the large oceanic population which spawns off Baja California and undergoes a long migration off Oregon, Washington, and British Columbia (Nelson, 1967). Utter and Hodgins (1971) have demonstrated the genetic isolation of these two populations.

The central Puget Sound population of Pacific whiting is of considerable importance. Previously unexploited, it became the object of an industrial-use trawl fishery in November 1965 (Hipkins, 1967). In 1983, 6,821 metric tons (t) were harvested from this stock, comprising 68 percent of the Puget Sound trawl landings and 15 percent of all groundfish landed commercially in Washington. Small groups of whiting occur in other areas of Puget Sound, although none has yet been commercially exploited. Whiting is also a major contributor to the recreational catch from fishing piers in Puget Sound, especially in August and September.

Distribution

Pacific whiting is one of the most abundant species of groundfish in Puget Sound. Commercial quantities of whiting are present in Saratoga Passage (Fig. 1) from September through December. During most years, about 70 percent (in numbers) of the catch in Saratoga Passage is comprised of adult fish. In some years, juveniles may dominate the catch, with the ratio of juveniles to adults increasing from south to north. Very few whiting in spawning condition have been observed in Saratoga Passage. These few were taken in or near Holmes Harbor during the late fall of 1982; however, there was not enough evidence to indicate this might be a significant stock separate from that which spawns in Port Susan. Results from hydroacoustic surveys performed during fall daylight hours in Saratoga Passage suggested that whiting (mainly juveniles) were the major component of a medium-to-heavy density layer from 35 m to the bottom in water less than 73 m deep. In water deeper than 73 m, a mixture of juvenile and adult whiting occupied a heavy density layer from the bottom to 18 m off the bottom. Little is known of the vertical movements at night in Saratoga Passage.

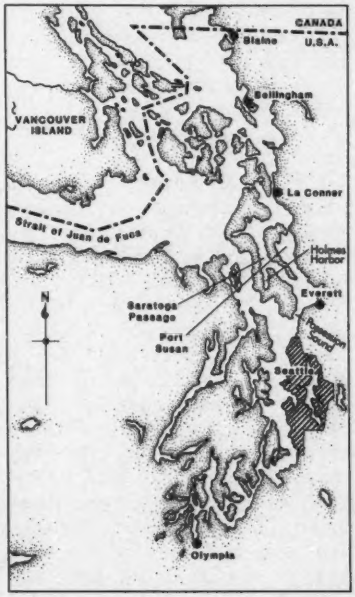

Figure 1.—Puget Sound and the Pacific whiting fishing grounds.

The abundance of Pacific whiting declines in Saratoga Passage during December and January. About the same time a large aggregation begins to form in Port Susan. These circumstances suggest that whiting may use Saratoga Passage as a staging area to complete maturation prior to entering the Port Susan spawning ground.

During the fall, few adult fish have been observed in Port Susan, but scattered small schools of juveniles have been present. During late January, the percentage of adult fish in the whiting biomass begins to increase rapidly. About 95 percent of the whiting caught in Port Susan during this time have been maturing or mature adults (Kimura and Millikan, 1977). Nighttime hydroacoustic surveys indicated dense schools of whiting 9-18 m thick from 4 to 7 m off the bottom in water depths of 110-145 m. During late February and March, schools of the same thickness have been observed hard on bottom, which may have been associated with spawning activi-

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Table 1.—Growth characteristics of Pacific whiting in Puget Sound, averaged from data collected 1965-74.

	Males		Females	
Age	Average length (cm)	Average weight (g)	Average length (cm)	Average weight (g)
2	27.5	151.7	26.8	142.1
3	31.5	212.1	31.4	216.6
4	34.0	256.0	34.8	284.7
5	35.5	284.8	37.3	342.3
6	36.5	304.9	39.2	390.7
7	37.1	317.4	40.6	428.9
8	37.4	323.8	41.6	457.5
9	37.6	328.1	42.4	481.3
10	37.8	332.4	42.9	496.6

Table 2.—History of catch (t) and effort for the central Puget Sound whiting fishery, 1965-83.

	Saratoga Passage		Port Susan		Combined	
Season	Catch	Trawl hours	Catch	Trawl hours	Catch	Trawl hours
1965-66	333.5	71	2,531.2	764	2,864.7	835
1966-67	1,025.4	279	3,728.9	973	4,755.6	1,252
1967-68	514.8	287	3,188.7	1,314	3,703.5	1,601
1968-69	763.9	320	3,468.3	1,049	4,232.3	1,369
1969-70	273.8	143	3,813.2	1,398	4,087.0	1,541
1970-71	182.7	62	3,365.2	2,241	3,547.9	2,303
1971-72		Negligible	1,895.4	1,506	1,895.4	1,506
1972-73		Negligible	1,122.4	731	1,122.4	731
1973-74		Negligible	2,284.7	1,071	2,284.7	1,071
1974-75	97.0	16	1,406.0	453	1,503.0	469
1975-76		Negligible	1,396.1	279	1,396.1	279
1976-77	380.2	24	1,244.4	231	1,604.6	255
1977-78	410.7	20	2,620.0	848	3,030.6	887
1978-79	115.2	6	4,362.6	764	4,477.8	770
1979-80		Negligible	4,490.1	569	4,490.1	569
1980-81	171.0	30	4,258.4	1,273	4,429.4	1,303
1981-82	1.2	2	4,618.1	1,007	4,619.3	1,009
1982-83	1,389.2	Unavailable	5,161.5	Unavailable	6,550.7	Unavailable

ty. During daylight hours in Port Susan, schools of whiting were more depressed, to about 40% of the nighttime thickness.

In summer, the fish disperse from the spring spawning grounds, and are commonly observed from piers near the surface along the shore, feeding on shrimps and small fishes.

Biology

The length at which 50 percent of the fish are mature occurs at 29 cm and 31 cm for males and females, respectively. A very small proportion of fish mature at 2 years of age. The proportion of mature individuals increases rapidly with age, and nearly all fish are mature by 7 years of age. Females grow faster than males, and appear to live longer. Females have been recorded up to 73 cm in length and age 15 years, and males up to 45 cm and 11 years (based on examination of otoliths surfaces). However, most of the fish that occur in the fishery range between 4 and 9 years old, and 32 and 45 cm in length. Growth characteristics are shown in Table 1. In comparison with Canadian observations of length at age in the Strait of Georgia (McFarlane et al., 1983), the central Puget Sound whiting appeared to be 2-4 cm shorter at age for ages 3 years and older. At age 2, the data indicated Puget Sound fish were 2-4 cm larger than the Strait of Georgia fish. This observation, and the fact that central Puget Sound whiting mature at a smaller size than do Strait of Georgia fish, may be related to stock response to several years of intensive commercial fishing in Puget Sound. Kimura et al. (1981) concluded that fish appear fully recruited to the exploitable population at age 6 or 7 years. The best estimate of the instanteous rate of natural mortality (M) is 0.65 (Kimura et al., 1981). Examination of age data has demonstrated that year-class strength can be quite variable (Fig. 2). The 1969, 1970, 1972, and 1973 year classes exhibited strong showings between 1972 and 1980.

The Fishery

The Puget Sound commercial fishery is centered in Saratoga Passage from October through December and in Port Susan from January through June. Table 2 shows the harvest history for 1965-83. Millikan (1970) reviewed the first 5 years of the central Puget Sound fishery and examined some of the problems of interpreting catch per unit of effort (CPUE). Because fishing vessels vary in efficiency, average CPUE will be affected by which vessels fish during a year. Also, market conditions determine not only who fishes, but effort levels as well. Analyses of CPUE are also confounded because whiting may be tightly schooled during the fishery and catch rates can be maintained by using echo sounders even when absolute abundance is low. When fishing effort is high, scattering of the schools may lower CPUE. Thus for this fishery, CPUE is not a useful statistic.

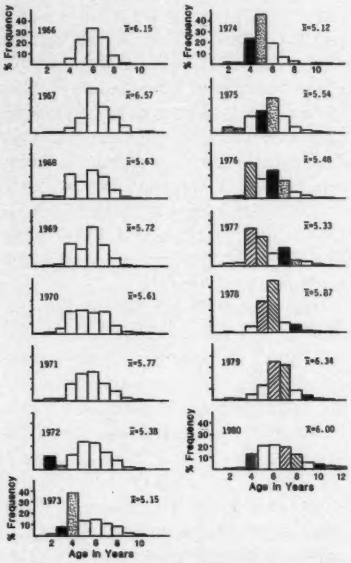

Figure 2.—Age frequency of female Pacific whiting from Port Susan.

From three to fourteen vessels have participated annually since the inception of the fishery. Vessels range in

length from 15.2 to 26.6 m, and from 39 to 112 gross tons. Most vessels utilize variations of pelagic trawls with telemetry, although a few vessels have utilized bottom trawls with moderate success. Fishing occurs during the day only in Saratoga Passage, and both day and night in Port Susan. Vessels land every day or every other day. Most of the harvest has been landed at Everett, Wash., but until 1983 between 10 and 30 percent were landed at LaConner, Wash. Landings now occur at Bellingham and Blaine in addition to Everett. The average price per metric ton to fisherman has gradually increased from $22 to $61 over the years. Since 1981, vessels with refrigerated holds have entered the fishery to supply whiting to be processed for human consumption. These vessels land daily.

Processing

Through 1980, the primary utilization of the central Puget Sound whiting resource was for industrial purposes. Between 450 and 800 t annually were sold as animal food, specifically for use as a major component in production of fish food pellets for salmonids. The bulk of the landings, however, was reduced to fish meal via a dry press method. Much of this meal was also used in making food for fish hatcheries in the Pacific Northwest, as well as being incorporated into food for chickens and swine in California.

In the spring of 1981, a market developed for human utilization of whiting that began to compete with industrial users. Over 900 t were landed for human food in 1981 and twice that was landed in the spring of 1982. Vessels with refrigerated holds would unload daily at Everett, and fish were trucked to the processing plant where they were headed and gutted by machine, washed, sealed, packaged, and frozen. The product was marketed in packages of various weights and distributed primarily in the Southern States. This process yielded about 50 percent food product and most of the remainder was rendered. During the 1983-84 season, all landings were sold to fish companies for human food.

There are currently four major buyers (all food fish companies), and more companies are becoming interested. Competition for the limited resource in Puget Sound in now acute, as the demand exceeds the supply by more than twofold.

Management

Because the resource of Pacific whiting in Puget Sound is of considerable importance, the Washington Department of Fisheries makes a substantial effort to assess its condition, monitor the fisheries, and implement management actions to prevent overharvest.

During the 1960's, the whiting resource assessment surveys in Port Susan were among the first on the west coast to employ hydroacoustic equipment to estimate absolute abundance. This was a period of rapid technical development, and considerable improvement was made in both equipment and methodology. For example, the hydroacoustic data from the 1969-70 surveys were analyzed with an analog integrator (which converted fish echo signals directly into fish densities). In 1971, a more versatile and accurate digital integrator was developed, and all subsequent data have been processed using this method of integration. Also, from 1969 through 1972, trawl catch densities (volume swept method) were used to scale acoustic output to give absolute or real density values. This method made the unrealistic assumption that trawl efficiency was 100 percent; in addition, the number of data points was often limited. In 1974, a fully calibrated echo sounding system became available, making it possible to obtain abundance estimates based entirely on acoustic measurements (Thorne, 1974). In 1975, acoustic densities based on net haul data were compared with densities determined from calibration measurements, and this resulted in an acoustic target value of -37 decibels per kilogram of whiting (Thorne, 1975). This standard value was used to calculate subsequent population estimates until 1983. Target values now vary depending on the size composition in schools of fish as determined from trawl hauls.

Thorne (1975) summarized hydroacoustic survey results in Port Susan from 1971 to 1975. Surveys were conducted from February through April with most of the effort occurring in March. Estimates of whiting abundance for the period range from a low of 8,000 t in 1971 to a high of 28,200 t in 1974, with no apparent trends. This fluctuation is due to variability in geographic scope between years and inadequate trawling to verify species composition of acoustic sign.

The first attempt at a comprehensive assessment of the central Puget Sound whiting population was by Kimura and Millikan (1977). Their report examined the 10 years of biological data collected during the 1965-74 seasons, and they presented a stock assessment which utilized yield per recruit and generalized production models. The best estimate of maximum sustainable yield (MSY) from this report was 3,600 t as derived from the generalized production model.

During the period 1971-76, catch levels moderated, and there was no apparent need for further assessment. However, in the 1978-79 period, landings exceeded 3,600 t, and another stock assessment was performed by Kimura et al. (1981). Virtual population analysis indicated that the 4,200 t average annual catch taken during the 1966-69 seasons represented a heavy exploitation rate, from a population biomass of about 10,300 t. Hydroacoustic estimates of biomass fluctuated greatly over the years, but the 1979 and 1980 surveys indicated population biomasses of 10,400 and 12,200 t, respectively. A new MSY estimate of about 4,500 t was derived from this latest stock assessment.

Because examination of age and length compositions indicated no strong year classes entering the fishery in 1980, and because hydroacoustic biomass estimates and fishery modeling indicated the population was being fully utilized, it appeared that a

conservative policy on future harvest was justified.

Under existing stock conditions, it was determined that an appropriate rate of exploitation would be 33 percent of the estimated biomass (Kimura et al., 1981). This rate would be used to determine the annual acceptable biological catch (ABC). Under this approach, the appropriate harvest during the 1979-80 season would have been about 4,050 t.

An estimated 4,500 t were taken, representing an exploitation rate of 37 percent. The fishery was closed by emergency regulation on 10 May 1980. The harvest guideline was not reached in 1981 and the fishery ceased naturally. The fishery was closed 3 April 1982 when the harvest reached the projected 4,626 t ABC. During 1983, the fishery was closed on 24 February when the apparent ABC was attained. More fish entered the grounds in March and the fishery was reopened for 4 days.

At this point, there is little data to support a theory that all whiting in Saratoga Passage are a distinct stock from those in Port Susan. For this reason, and because it is anticipated that very intense fishing pressure on whiting will occur as they concentrate in Port Susan, it is appropriate to continue to consider the fish in Saratoga Pass, Possession Sound, and Port Susan as one stock. The harvest guideline of one-third of the peak acoustic biomass of whiting in Port Susan will remain. The peak whiting biomass will be determined by averaging the acoustic estimates obtained between mid-February and mid-April and adding the cumulative seasonal catch (including that from Saratoga Passage). Fishing may be suspended prior to that time if catches exceed one-third of the most recent biomass estimates.

In the future, research should focus on improvement and standardization of hydroacoustic survey techniques; delineation of the central Puget Sound population and other groups of whiting in Puget Sound; and a better understanding of the biological parameters and population dynamics of this important resource.

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Historical Review of the Coastal Pacific Whiting, *Merluccius productus*, Fishery

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Introduction

The Pacific whiting, *Merluccius productus*, resource found off the west coast of the United States has been exploited commercially since before 1900 by the U.S. fishing industry and since 1966 by foreign fishing fleets (Jow, 1973; Forrester et al., 1978). The U.S. domestic fishery has two components: The traditional shore-based fishery, which consists of the catching and processing of fish by U.S. fishermen and processors, and the recently developed joint-venture fishery, which consists of the delivery and sale of fish caught by U.S. vessels to foreign processing vessels on the fishing grounds. The U.S. fishery for Pacific whiting was small in comparison to the foreign fishery whose annual landings from 1966 to 1981 averaged nearly 138,000 metric tons (t) per year. The development and growth of the joint venture fishery in the last few years have greatly increased the U.S. catch of Pacific whiting. This paper provides a historical review of the U.S. and foreign Pacific whiting fishery with emphasis on the changes which have occurred in the fishery since the enactment of the Magnuson Fishery Conservation and Management Act of 1976. (Magnuson Act).

U.S. Fishery for Pacific Whiting

Until the development in 1978 of Pacific whiting joint venture fisheries between U.S. fishermen and foreign fishing interests, the U.S. fishery for Pacific whiting off the Washington, Oregon, and California coasts was relatively minor in terms of effort, landings, and value. The segment of the U.S. fishery primarily composed of the delivery of catch to shore-based processing facilities is commonly referred to as the "shore-based fishery." This fishery began off California before 1900 (Jow, 1973). Most catches were made incidentally during the pursuit of more valuable species and were either discarded or, as was the case in northern California, delivered with other low-valued species to reduction plants producing animal food. From 1959 to 1966, the average annual landing in California was about 225 t (Nelson, 1970).

In 1964, the Bureau of Commercial Fisheries (BCF) demonstrated that large whiting catches to 60,000 pounds per half-hour haul could be achieved off Washington and Oregon using newly developed depth telemetry systems on large midwater trawls (McNeeley et al., 1965). In 1966, the BCF and Economic Development Administration in cooperation with the Grays Harbor Regional

Soviet BMRT-class factory stern trawler (top photo) used in their Pacific whiting fishery. At bottom, a catch of Pacific whiting is delivered to a Soviet processing vessel from a U.S. stern trawler (background) in a joint-venture fishery.

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Planning Commission supported a study to determine the economic feasibility of establishing a commercial whiting fishery in waters off Washington. In that year, a small exploratory fleet of four vessels began fishing for whiting and delivered 5,166 t to a reduction plant located in Aberdeen, Wash.

The BCF chartered 10 vessels in 1967 to begin the full-scale study of feasibility, and over 12,000 t were landed. In the absence of sustained government support and adequate prices for fish meal, landings declined by two-thirds in 1968. Processors simply were not able to pay ex-vessel prices to fishermen that were competitive with prices for traditional groundfish species. Subsequently, relatively low levels of landings (about 1,000 t per year for 1981-83) for animal food production have continued, and there have been sporadic, small, independent efforts to create markets for whiting fillets and headed and gutted products. The domestic market for Pacific whiting food products is relatively small, but growing, and is met mostly by a winter fishery pursued in Puget Sound, Wash.

One of the primary objectives of the Magnuson Act when implemented in 1977 was to create a situation which would encourage the development of U.S. fisheries for species which were underutilized by the U.S. fishing industry. The Pacific whiting resource was one of the species considered underutilized by the industry and one which offered a potential for further development. Unfortunately, the economic, marketing, and processing problems resulting from the soft texture in the flesh of Pacific whiting (Anderson, 1985; Kabata and Whitaker, 1985; and Nelson et al., 1985) which hindered development of the fishery prior to 1977 have continued to hinder development since 1977.

In September 1978, the Marine Resources Company[1] of Seattle, Wash., initiated an experimental joint-venture fishery for Pacific whiting between two U.S. trawlers and two Soviet factory trawlers. This initial joint venture landed 856 t of whiting in about 1½ months of fishing. The operation proved that U.S. fishermen, when given a high-volume market for a low-valued species, could operate profitably and could produce the large catches of whiting required to make the operation successful. The operation also demonstrated that high quality products could be produced from whiting immediately processed and frozen at sea and that these products could be marketed competitively in the international market by Marine Resources Company.

The success of the 1978 joint venture fishery led to an expanded fishery in 1979 which included seven U.S. trawlers and 11 Soviet factory trawlers acting as processing vessels. (There were never more than seven Soviet factory trawlers in active participation at any one time.) The joint venture fishery landed 8,834 t of whiting in 1979 which represented about a tenfold increase over the initial 1978 fishery. Since 1979, the joint venture has continued to expand. U.S. fishermen have conducted joint venture fisheries with Poland, Bulgaria, and Greece in addition to the Marine Resources Company's Soviet joint venture. In 1983, U.S. vessels landed 72,100 t of whiting in the joint venture fishery. The annual catches of whiting and numbers of U.S. trawlers and foreign processing vessels participating in the fishery are shown in Table 1 for 1978-83.

The joint venture Pacific whiting fishery from 1978 to September 1982 was primarily managed through a preliminary management plan for groundfish prepared by the U.S. Department of Commerce and by Department of Commerce restrictions on the permits issued to foreign vessels participating in the joint venture fishery. Since September 1982 the fishery has been managed by both restrictions placed on the fishing permits of the foreign processing vessels and by the Fishery Management Plan for groundfish prepared by the Pacific Fisheries Management Council. The primary restrictions in the joint venture fishery, in addition to a limit on the catch of Pacific whiting, have been 1) strict limitations on the allowable retention of groundfish species other than Pacific whiting; and 2) restriction from 1978 through 1980 on the operation of the foreign processing vessels in the 3-12 mile area adjacent to the U.S. 3-mile territorial limit. Since 1981, foreign processing vessels participating in joint ventures have been allowed to work within the 3-12 mile area.

Foreign Fishery for Pacific Whiting

The development of the foreign fishery for Pacific whiting has previously been described by Hitz (1970), Pruter (1976), Forrester et al. (1978), and French et al. (1981). The foreign fishery for Pacific whiting was initiated in 1966 by the U.S.S.R. and Japan. Soviet and Japanese fisheries expanded southward from the Gulf of Alaska in search of areas with a high abundance of Pacific ocean perch, *Sebastes alutus*. During the early years of the fishery, Pacific ocean perch was a secondary target species in the Soviet fishery and a primary target species of the Japanese fishery. During the first year of operation, the Soviet fleet landed 128,000 t of whiting and Japan landed 136 t of assorted groundfish species.

The foreign fishery continued to grow for the next 9 years and peaked in 1976 with a catch of 231,000 t of whiting (Table 2). During this 9-year period the Soviet and Japanese fleets

Table 1.—The catch of Pacific whiting in the joint-venture fishery off Washington, Oregon, and California, 1978-83, and the number of U.S. and foreign processing vessels.

Year	Pacific whiting catch (t)	Number of U.S. vessels	Number of foreign processors
1978	856	2	2
1979	8,834	7	11
1980	27,537	16	11
1981	43,557	22	20
1982	67,437	21	15
1983	72,100	19	16

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

were joined by vessels from Poland and the German Democratic Republic (East Germany) in 1973, the Federal Republic of Germany (West Germany) in 1975, and Bulgaria in 1976. Regulation of the foreign fishery was extremely limited during this period. Bilateral agreements between the United States and the foreign countries were the primary means of control. These agreements generally included time-area closures, catch limits, and prohibitions on the retention of Pacific halibut, *Hippoglossus stenolepis*; salmon, *Oncorhynchus* spp.; and crab. The various conditions of bilateral agreements which the United States established with the U.S.S.R., Poland, and Japan and which affected the fisheries of these nations for Pacific whiting, are provided in Forrester et al. (1983).

The passage of the Magnuson Act by the United States in 1976, and its implementation in March 1977, gave the United States exclusive management authority over the fishery resources occurring within 200 miles of its coast. The Magnuson Act authorized the establishment of fees and permits for the licensing of foreign fishing vessels; catch allocations for foreign fisheries and poundage fees for fish caught; the enforcement of time, area, and gear restrictions; requirements for submission of detailed catch and effort data; and the placement of fisheries observers on foreign fishing vessels. For 1977, the total allowable level of foreign fishing (TALFF) for Pacific whiting was set at 123,000 t. Only the U.S.S.R. and Poland were permitted to fish for Pacific whiting that year. Additionally, strict by-catch limits were placed on the incidental catches of other groundfish species taken in the Pacific whiting fishery, and the fishing season was limited from 1 June through 31 October. The catch restrictions imposed by the United States in 1977 reduced the foreign catch of Pacific whiting to 127,000 t, compared with the peak historic catch of 231,000 t in 1976 (Table 2).

Since 1977, the foreign catch of Pacific whiting has continued to decline. The U.S.S.R., Poland, and Mexico received allocations for Pacific whiting in 1978 and 1979 (Mexico, however, did not use its allocation). In 1980, Soviet fishing privileges within the U.S. 200-mile zone were rescinded as one of the economic sanctions imposed by the United States in response to the Soviet invasion of Afghanistan, thus ending their 14-year direct participation in this fishery. Poland's 9-year participation in the Pacific whiting fishery was ended in 1982, as a result of the termination of its fishing privileges by the U.S. in response to the implementation of martial law in Poland. Bulgaria was permitted to fish in 1981 and 1982. Bulgaria's catch of 7,100 t of Pacific whiting in 1982 represented the smallest annual foreign fishery for whiting since the U.S.S.R. initiated the fishery in 1966. There was no directed foreign fishery for whiting conducted in 1983.

Table 2.—Annual catches of Pacific whiting taken off the coasts of Washington, Oregon, and California by foreign nations, 1966-83[1]

Nation	Bulgaria	E. Germany	W. Germany	Japan	Poland	U.S.S.R.	Total	TALFF[5]
Year								
1966				[4]		128,000	128,000	
1967				[4]		195,092	195,092	
1968				[4]		67,896	67,896	
1969				98		109,225	109,323	
1970				1,400		200,754	202,154	
1971				799		146,726	147,525	
1972				307		111,269	111,576	
1973		[2]		3,782	2,200	139,060	145,042	
1974		[2]		8,259	44,354	156,708	209,321	
1975		2,000	[3]	3,214	41,542	155,405	202,161	
1976	24,200	26,000		3,334	23,668	154,129	231,331	
Magnuson Act implementation								
1977					16,805	110,208	127,013	123,200
1978					26,721	70,106	96,287	120,000
1979					18,073	96,837	114,910	161,400
1980					44,023		44,023	120,000
1981	7,023				63,342		70,365	95,000
1982	7,089						7,089	35,000
1983							0	35,500

[1]Catch data for 1966-76 from Murai et al. (1981). Catch data for 1977-82 from unpublished data from the Northwest and Alaska Fisheries Center, NMFS, NOAA, 2725 Montlake Blvd. E, Seattle, WA 98112.
[2]East Germany conducted a fishery in 1973 and 1974 but catch statistics are not available.
[3]West Germany conducted a fishery in 1975 but catch statistics are not available.
[4]Groundfish fishery conducted by Japan but no record of the Pacific whiting catch in that fishery.
[5]TALFF denotes "Total Allowable Level of Foreign Fishing" under the Magnuson Act.

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Economics of the Pacific Whiting, *Merluccius productus*, Fishery

ERIC ANDERSON

Introduction

Interest in the economics of Pacific whiting, *Merluccius productus*, production and consumption has been stimulated in recent years by expanding U.S. participation in the fishery formerly dominated by foreign fishing and processing. This has raised several questions within the U.S. fishing industry: 1) Will it be profitable for additional U.S. fisherman and processors to enter the fishery? 2) What configuration will the U.S. Pacific whiting industry take? and 3) What will be the nature of markets for Pacific whiting products? This paper summarizes the conclusions of several reports and studies which bear on these questions.

The answers to the questions will be determined by the forces of supply and demand for Pacific whiting products and, to some extent, by government action. The first subject discussed here is potential markets for the various Pacific whiting products, and constraints on the demand for these products. This discussion is followed by an examination of the cost factors which affect supply, and which determine how the fish will be caught and processed.

Markets

The most obvious potential markets for U.S.-processed Pacific whiting products are those which currently consume the output of the foreign and joint-venture fisheries. However, these markets are primarily in Communist Bloc countries which do not have normalized trade relations with the United States. While it is possible that provisions for trade in Pacific whiting and other fishery products could be negotiated with these countries, it is not considered likely (Earl R. Combs, Inc.[1]). Therefore, entirely new markets will probably have to be found.

Although some authors suggest that Pacific whiting fillets, both fresh and frozen, could be successfully marketed (Pacific Fishery Management Council, 1982; and Richards[2]) this seems unlikely due to the problem of flesh fragility and rapid decay.

Another possibility is that Pacific whiting could compete in the huge frozen groundfish fillet block market. There are several obstacles to this development which some writers feel are insurmountable (Kramer, Chin, and Mayo, Inc.[3] and Richards[2]). To begin with, the problems of parasitism and flesh fragility will probably prevent successful penetration of the highly quality-conscious western European segment of the market (Earl R. Combs, Inc.[1]). In the United States, the same problem will leave Pacific whiting at a serious competitive disadvantage if attempts are made to sell it in retail stores as frozen breaded or battered portions cut from blocks. This might change if consumers could be persuaded to adopt the cooking method required to avoid enzymatic softening of the flesh, namely deep-fat frying without first thawing. However, consumers may resist changing their cooking habits, and since they are unfamiliar with this species, a great deal of consumer education effort may be required.

One marketing channel in which handling methods could be carefully controlled, thereby reducing the quality impediment, is the sale of frozen portions to institutional buyers, who usually deep-fry their products (Earl R. Combs, Inc.[1]). To make inroads into this segment of the groundfish market, it will be necessary to overcome the resistance of buyers to frying without first thawing the fish (Fisherman's Marketing Association of Washington[4]) and to assure the buyers of reliable supply

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[1]Earl R. Combs, Inc. 1979. Study of the economics of the Pacific hake fishery. Unpubl. manuscr. prep. for Coos-Curry-Douglas Economic Improvement Association and the Oregon Department of Economic Development. Earl R. Combs, Inc., 2737 77th S.E., Mercer Island, WA 98040.

[2]Richards, J. A. 1982. Economic information for the management of the groundfish fisheries of Washington, Oregon, and California. Unpubl. manuscr., 117 p. Northwest Reg. Off., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point, Way, N.E., Seattle, WA 98115.

[3]Kramer, Chin, and Mayo, Inc. 1982. System strategy for California, Oregon, and Washington fishing industry and public ports infrastructure needs and assessment, final report and technical analysis. Unpubl. manuscr., prep. for West Coast Fisheries Development Foundation and the National Oceanic and Atmospheric Administration. Kramer, Chin, and Mayo, Inc., 1917 1st Ave., Seattle, WA 98101.

[4]Fishermen's Marketing Association of Washington. 1980. Offshore factory trawler demonstration project. Unpubl. manuscr., prep. for West Coast Fisheries Development Foundation and National Oceanic and Atmospheric Administration under cooperative agreement 80-ABH-00052, 49 p.

quantities of consistent quality. The latter is not an easy task for any new industry. Converters, the firms which cut blocks into fish sticks and portions to varying specifications of their customers, may prefer not to buy blocks of a species which can be sold only to a limited class of customers. Therefore, it may be that Pacific whiting processors will have to invest in the capability to do their own converting and sell directly to institutional customers if they are to market blocks successfully (Earl R. Combs, Inc.[1])

Other product forms which have been considered for Pacific whiting include such products as frozen blocks of headed and gutted (H&G) fish, precooked breaded portions, chowders (where the flesh characteristics are less important), cured products, and industrial products such as meal, oil, and fertilizer. Some or all of them may eventually play minor roles in the industry, but the markets for these product forms are not throught to be large (Earl R. Combs, Inc.[1]). Two studies have been released (one based on actual experience) which predict that on-board heading and gutting will be profitable (Philbin, 1980; Fishermen's Marketing Association of Washington[4]).

Shore-based production of frozen H&G whiting is currently supported by the relatively small Puget Sound, Wash., stock. This production is profitable because the fish are close to shore, do not deteriorate as rapidly as do the oceanic variety, and are smaller than the oceanic stocks. Their smaller size makes them attractive to low income and ethnic markets in eastern and southern states.

One problem not considered in the cited studies is that H&G Pacific whiting is a product for which there is a relatively small market in the United States, and for which there are few close substitutes, so any large-scale increase in production may depress the price significantly. However, Earley (1981) suggests that the product could be marketed successfully in Mediterranean countries, despite quality problems.

Assuming that markets can be found, there are still obstacles to profitability. One, which can be categorized as a demand phenomenon, is the low wholesale prices at which Pacific whiting products must be sold. The prices are constrained by the fact that other groundfish, including other species of whiting, are higher quality substitutes for Pacific whiting in the whitefish fillet and block market. Since Pacific whiting maximum sustainable yield (MSY) is small compared to total U.S. and world groundfish consumption (175,000 metric tons (t) Pacific whiting MSY; about 1,200,000 t round weight U.S. groundfish consumption in 1981), producers of Pacific whiting products face a more or less rigid upper limit on the price they receive. They cannot hope to significantly replace other species unless they offer their product at a price that is somewhat lower than this upper limit. It has not thus far proved profitable to do so.

Only if and when growth in world demand for groundfish outstrips growth in world supply will the prices of all groundfish products, including Pacific whiting, rise enough to make expanded Pacific whiting processing worthwhile, assuming that costs do not rise proportionately (not a foregone conclusion). There is some reason to believe that this rise in demand might eventually occur. First, demand for groundfish can be expected to grow as population and income in North America and Europe grow (Kramer, Chin, and Mayo, Inc.[3]). However, income growth is not certain, and because the prices of substitute protein sources like beef, pork, and poultry must be assumed to remain approximately constant, the price of groundfish is expected to be relatively unresponsive to increases in demand. The rapid growth in demand for frozen groundfish products by fast food operators and retail food chains (which constitutes a structural change in demand) is apparently near an end (Kramer, Chin, and Mayo, Inc.[3]). Second, while there is room for expansion in the New England and South American whiting harvests (Richards[2]), maxima will be reached there eventually, and total world production of groundfish will stabilize.

The only other hope for a rise in the price ceiling is a technological improvement in the processing of Pacific whiting which would eliminate its tendency to deteriorate. This would raise the quality to a level approximately equal to that of other species and allow Pacific whiting to be sold at a comparable price.

Processing

Onshore

Turning now to supply aspects of the Pacific whiting industry, we can make some general statments about the relative merits and costs of at-sea and on-shore processing, and about why foreigners are processing large quantities of Pacific whiting and U.S. firms are not. Currently, the limited U.S. processing of this species is done on shore, where processing is generally less expensive than at sea for several reasons. For production on a small scale, there already exists plant space on shore which can be used for expansion of Pacific whiting processing at times when it is not being used for other species. All that is required in some additional equipment and labor (Earl R. Combs, Inc.[1]). Thus, the current low level of U.S. production can be sustained or slightly increased at relatively low cost. This cannot be said of U.S. motherships or factory trawlers, of which there are only a few, all fishing for other species. For a large-scale expansion of the industry to occur, additional plant space or vessels would have to be built. Onshore plants are cheaper to construct than are factory ships of the same capacity, unless land costs are high enought to reverse the relationship. Foreign-built factory trawlers could be purchased new or used at much lower prices than new U.S.-made vessels (Earley, 1981), but they are prohibited from fishing in U.S. waters by the Jones Act. A similar prohibition against foreign-built motherships

no longer applies, since the U.S. Customs Service has ruled that fish processed aboard such ships may be landed in U.S. ports if the ships are registered in the United States.

With regard to variable costs, shore plants have some advantages over processing ships, since they do not require fuel to propel them, and because shore-based processing labor can be paid less than workers who must be compensated for the inconvenience and discomfort of living at sea for long periods. On the other hand, at-sea processing enjoys exemption from some of the taxes, pollution abatement regulations, and waste disposal costs that are imposed on shore-based plants.

More importantly, however, there are two features of Pacific whiting biology which may explain the failure of the existing small-scale on-shore processing operations to expand appreciably. First, the fish migrate along the U.S. west coast during the summer fishing season, so that the stock is rarely within practical fishing range of any given shore plant for more than 3 months (Earley, 1981). It is simply not economical to build new plant capacity dedicated to a low-valued fish which is available less than 3 months a year. Since most of the other Pacific coast species which might also be processed in a new plant are already at or near maximum yield (Pacific Fishery Management Council, 1982), the expansion would have to be supported mostly by Pacific whiting. Processing ships, in contrast, can participate in Alaska groundfish fisheries during the winter when Pacific whiting are not available.

Second, the high incidence of parasitic infestation of the flesh can result in unacceptable product quality when the fish must remain in the boats' holds for more than 2 days (Earl R. Combs, Inc.[1]; Philbin, 1980), even when the hold is refrigerated. This requires short trips in which actual fishing time is only a small proportion of total trip length. There is some controversy about whether product quality can be maintained after even a few hours in the hold (Richards[2]).

Offshore

Offshore processing takes two forms: Delivery at sea to motherships by catcher boats and the combination of fishing and processing on a factory trawler. Motherships and catcher boats are used primarily in joint ventures, while factory trawlers are used by the foreign fishing fleet. Delivery at sea is less costly to fisherman than delivery on shore because 1) less time and fuel are diverted from fishing to running to and from port, delivery is made to the processor on the grounds, and some supplies are provided by the mothership; 2) refrigeration in the fish hold is unnecessary since delivery can usually be made very soon after the fish are caught; 3) the fishing vessel crew can be smaller because the fish are not brought on board the catcher boat, but are transferred to the processor while still in the detachable codend; and 4) fishing boats can stay with the moving schools of whiting, instead of having to spend time searching for them after returning from a delivery in port.

As a consequence of these cost advantages, fisherman are willing to fish for at-sea delivery for a lower ex-vessel price than they require for delivery to on-shore processors. For comparable harvest volumes, the difference is about $0.02 per pound, according to Richards[2]. At the ex-vessel prices paid by joint venture buyers in the recent past (about $0.06 per pound in 1982), there have been more applicants for fishing contracts than there are openings (McNair, 1982). It should be pointed out that there is no single price which is required to persuade fisherman to participate in joint ventures or in shore-based fishing. Rather, there is a supply function; more fishermen participate when the price is higher than when it is lower.

Of the two fishing-processing modes which do not involve catcher-processors, at-sea delivery is the mode of operations which is less costly for fisherman, while on-shore processing may be the mode which is cheaper for processors (not counting the cost of purchasing fish from fisherman). What matters in determining the final configuration of the industry, if an entirely domestic industry does develop, is the total cost of harvesting and processing combined, along with considerations like the feasibility of maintaining adequate quality and the availability of off-season employment in other fisheries. Which of the two modes satisfies these criteria is not yet known, but the quality and limited season considerations would appear to be the deciding factors in favor of at-sea delivery and processing, at least for the major proportion of the output (Earl R. Combs, Inc.[1]) It is possible, however, that the use of large, efficient fishing vessels with improved refrigeration, improved procedures for unloading fish at shore plants, and changes in processing procedures could negate the apparent advantage of at-sea processing (Richards[2]).

The third possible mode, combining fishing and processing in a factory trawler, has some advantages over mothership fishing. First, the time interval between capture and processing can be even shorter than when the catch must be transferred to the mothership. The risk of losing a codend full of fish during the transfer operation is eliminated. The harvest rate can easily be matched to the ship's processing capacity, so there need not be any backup of harvested fish waiting to be processed (Earl R. Combs, Inc.[1]). Finally, there is no need to arrange for a fleet of catcher boats, through contract or purchase, in each fishery that the vessel participated in (Earl R. Combs, Inc.[1]).

One disadvantage of a catcher-processor, compared with a mothership and catcherfleet, is inflexibility of harvest capacity, especially when the ship fished in fisheries or seasons where the optimal catcher-vessel size varied markedly. Another problem is the large size of catcher-processors: One study of Alaska groundfishing costs and returns suggests that, under average conditions, the optimal fishing vessel size is only about 85 feet (Kramer, Chin, and Mayo, Inc.[3]). A similar cost structure may exist in the Pacific whiting fishery. Processing,

however, may embody substantial economies of scale, with the optimal size being considerably larger than is practical in a factory trawler. At best, a factory trawler can only compromise between the optimal scales of its two functions. Finally, there is the high acquisition cost imposed by the Jones Act.

Earley (1981) concluded that, given the constraints raised by the Jones Act and the difficulty of training or importing skilled processing labor, profitable factory trawler operations on Pacific whiting are not feasible for U.S. firms. If those constraints were removed, profitability might be achieved.

The few existing U.S. factory trawlers have more attractive alternative opportunities year-round in Alaska (i.e., the *Arctic Trawler's* frozen cod fillet operation). One of them was used on an experimental basis for Pacific whiting fishing and processing in 1980 (Fishermen's Marketing Association of Washington[4]), and it was found that production of frozen fillet blocks was not profitable. The experiment did suggest that production of H&G whiting by factory trawlers might prove commercially successful, but no further work in that direction has been done.

With factory trawler fishing for Pacific whiting shown fairly convincingly to be economically unfeasible, the question arises, "Will domestic mothership fishing soon characterize the fishery?" Earl R. Combs, Inc.[1, 5] predicted that it will, while the more recent reports by Kramer, Chin, and Mayo, Inc.[3] and Richards[2] assert that rapidly rising costs and the low wholesale price of Pacific whiting products will continue to discourage entry of U.S. processing into the fishery, beyond the present small-scale shore-based activity.

Joint Ventures

Operators of foreign processing ships have found it worthwhile to purchase Pacific whiting from U.S. fishermen at sea, at ex-vessel prices sufficiently high to attract a large number of fishermen to these joint ventures (Kaczynski[6]). Foreign processing vessels have lower costs than U.S. motherships would; in some cases, their actual direct costs may be lower than those of U.S. ships, and another important factor is that these ships have often been excluded from the extended economic zones of countries whose waters they were built to fish in. Therefore, they have limited alternative opportunities (that is to say, low opportunity cost), and rather than let them stand idle, their owners are willing to use them even when profits are low or negative. The same is true of the skilled crews of these vessels. In addition, since the factory ships used in Pacific whiting joint ventures are owned by Communist Bloc nations, profit is a secondary objective in their operation, with conservation of foreign exchange and employment playing more important roles (Earley, 1981). Furthermore, as a result of the U.S. "fish and chips" policy, foreign countries have been agreeing to operate joint ventures as a condition of receiving direct harvest allocations. It may be that receiving this allocation is even worth sustaining losses in their joint venture operations. This is not true of the Soviet Union, which participates in the largest Pacific whiting joint venture, but which for political reasons receives no allocation. But political conditions can change, and it has been suggested that U.S. fishermen could successfully engage in collective bargaining or obtain government assistance in negotiating a higher ex-vessel price for their joint venture catch (Richards[2]).

On the basis of the factors described above, Kramer, Chin, and Mayo, Inc.[3], and Richards[2] concluded that for the foreseeable future, the Pacific whiting industry would continue to be dominated by joint ventures consisting of U.S. fishermen selling their catch to foreign processors. In this form, the industry will expand in the next few years, with the number of U.S. trawlers involved expected to increase, at least slightly. The additional vessels will be largely drawn from the existing west coast fresh groundfish fleet, converted to midwater trawling—and, to some extent, from converted Alaska crabbers. Some new vessels may also be constructed. The west coast trawlers will be attracted to the fishery despite the continuing opportunity to harvest traditional species of groundfish.

Richards[2] addresses the issue of whether permitting joint ventures is harmful to the development of domestic processing interest and capability. He concludes that it is not, because the two modes of fishing take place in different areas of the ocean: Offshore and inshore. This minimizes the effect that each fleet has in reducing the abundance of the stock on which the other is fishing, which would increase fishing costs and the ex-vessel price which must be paid the processors. It should be observed, however, that while this may be true in the short run, in the long run joint-venture fishing may affect the abundance of inshore Pacific whiting if all the whiting are members of a single stock. In addition, joint venture processors increase the competition for whiting fisherman, probably driving the ex-vessel price up. Moreover, it is possible that the nations now engaged in joint-venture processing might become importers of U.S. processed Pacific whiting products if joint ventures were prohibited. But, as noted above, this may be unlikely, and for reasons already discussed, it is probable that Pacific whiting processing would be unprofitable for U.S. firms even in the absence of joint ventures.

Conclusion

The evidence presented in the literature on the economics of Pacific whiting suggests that, for the near future, and possibly for the long run,

[5]Earl R. Combs, Inc. 1979. Prospectus for development of the United States fisheries. Unpubl. manuscr. prep. for NOAA's Fisheries Development Task Force. Earl R. Combs, Inc., 2737 77th S.E., Mercer Island, WA 98040.

[6]Kaczynski, V. 1981. Foreign fleets in the N.E. Pacific hake fisheries: Economic efficiency analysis. Instit. Mar. Stud. Univ. Wash., 3707 Brooklyn Ave. N.E., Seattle, WA 98105. Unpubl. manuscr., 98 p.

too, the industry will be primarily characterized by joint ventures. Action by the United States to restrict joint ventures would likely not result in large-scale expansion of domestic processing, and would sharply reduce opportunities for domestic fishermen. Joint ventures will probably expand, if permitted to do so, and will involve somewhat greater numbers of U.S. fishing vessels. Processed products from the fishery will continue to flow to the Communist Bloc nations, with some of the output being exported by them to other parts of the world.

Acknowledgments

I would like to thank Thomas Dark, Jack Richards, and Edward Ueber, National Marine Fisheries Service, NOAA, for helpful suggestions and comments.

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Harvesting Technology in the Pacific Whiting, *Merluccius productus*, Fishery

CHARLES W. WEST

Introduction

For any fishery to develop, several interdependent factors must come together. In the simplest terms, these elements include: A resource capable of sustaining some reasonable level of exploitation; adequate demand for the products of the fishery; and appropriate harvesting technology. When dealing with high-volume, low-value fisheries such as the Pacific whiting, *Merluccius productus*, fishery, it is particularly important to have efficient, economical harvesting techniques whereby large quantities of fish may be located and captured at minimal expense. In part, the success of the current fishery can be attributed to the development of such techniques. This paper will review the evolution of harvesting technology and discuss state-of-the-art gear presently in use.

Evolution of Gear Types

Nelson (1970) and Johnson and High (1970) give good detailed descriptions of early domestic efforts to evaluate and exploit the whiting resource off the coasts of California, Oregon, and Washington, and their discussions of gear will be summarized here. During the 1950's and early 1960's, large incidental catches of Pacific whiting in bottom trawl fisheries targeting on flatfish and Pacific cod, *Gadus macrocephalus*, indicated that there was a substantial resource. Due to the poor keeping qualities of the fish, whiting bycatches were discarded at sea or sold as raw material for mink and pet foods, and no interest in establishing a directed fishery developed until 1964. At that time the Bureau of Commercial Fisheries (BCF) started a demonstration fishery for whiting off the coast of Washington (Nelson, 1970). The fish was delivered to a processing plant in Aberdeen, Wash., where it was used to manufacture fish meal and fish protein concentrate.

While whiting are occasionally found in bottom waters and are thus available to bottom trawls, they occur more commonly in large dense schools in midwater. To capture them effectively, it was necessary to develop midwater trawling techniques, a technology that was still relatively primitive as late as the mid-1960's.

The BCF Exploratory Fishing and Gear Research Base in Seattle, Wash. (later the National Marine Fisheries Service (NMFS), Northwest and Alaska Fisheries Center) undertook in 1960 to develop a midwater trawling system that was to evolve into the Cobb pelagic trawl and its derivatives. Unlike modern midwater trawls, the Cobb pelagic trawl (Fig. 1) featured small mesh, 76 mm (3 inches) stretched measure or less, throughout all sections of the trawl and tapered relatively quickly from the large mouth opening to the narrow codend. Aluminum hydrofoil doors were designed for use with this trawl. A pressure-sensing trawl depth telemetry system utilizing electo-mechanical towing warps for depth data transmission was developed. With this system, the trawl's depth could be adjusted to keep it "on the fish," as detected by the ship's echosounder.

The Cobb pelagic trawl and its derivative, the BCF Universal trawl, were used to capture large quantities of whiting during the subsidized demonstration fishery mentioned above. Despite the effectiveness of the Cobb and Universal trawls, there were problems inherent in their designs that have been ameliorated during subsequent developments in pelagic trawl design. The small mesh sizes in the forward parts of these large trawls contributed a great deal of towing resistence, adversely affecting towing speed and vessel maneuverability. The abrupt (relative to later pelagic trawl designs) body tapers excited escape reactions among the fish within the trawl, resulting in excessive "gilling" in the after parts of the body of the trawl. The special towing warps required for the depth telemetry system were expensive, and the electrical conductors within the warps were prone to failure.

Nevertheless, the contributions of the BCF work should not be overlooked. Midwater trawling was shown to be an effective harvesting method for whiting, and West Coast skippers became familiar with the techniques involved. The importance of reducing drag through trawl design was shown, as was the desirability of taking advantage of the behavioral characteristics of the fish. These experiences also demonstrated that some form of trawl telemetry was essential to successful midwater trawling.

Further evolution in whiting gear designs came with the entrance of foreign fishing fleets into the fishery.

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When large fleets from the U.S.S.R. first began fishing off the West Coast for whiting and Pacific ocean perch, *Sebastes alutus*, in 1966, several different gear types were employed. Bottom trawls, midwater trawls, and midwater pair trawls were used, depending on fishing conditions and vessel capabilities. While whiting and Pacific ocean perch were the target species, incidental catches of flatfish; sablefish, *Anoplopoma fimbria*; Pacific cod; and other species were substantial. Between 1966 and 1976, fleets from other Eastern Bloc nations entered the fishery, using essentially the same vessel and gear types.

The passage of the Fisheries Conservation and Management Act (FCMA) in 1976 had a profound impact on the fishery. Catches by the foreign fleets were brought under U.S. control, and strict limits were placed on acceptable levels of bycatch of many benthic species. Foreign vessels were required to accept U.S. fishery observers who prepared independent estimates of catch sizes and composition and who obtained detailed descriptions of gear types and methods used. While catch quotas for whiting remained relatively generous for the foreign fleets in subsequent years, the restrictions placed on catches of other species encouraged the foreign fleets to fish more selectively on whiting while avoiding the other species. This change in focus of effort required the development and adoption of more selective gear.

By 1976, the fishing vessels in the Soviet and Polish whiting fleets were almost exclusively large independent stern trawlers, BMRT's of the *Mayakovskii* class and RTM's of the *Atlantik* class, both with their own processing equipment and freezer holds. These large vessels, 270-277 feet (82-85 m) overall with over 2,000 horsepower (Hitz, 1970), were capable of towing large bottom or midwater trawls. Most vessels fishing exclusively for whiting towed midwater trawls, while a few towed bottom gear until the catch quotas for incidental species had been reached, then switched to strictly midwater operations.

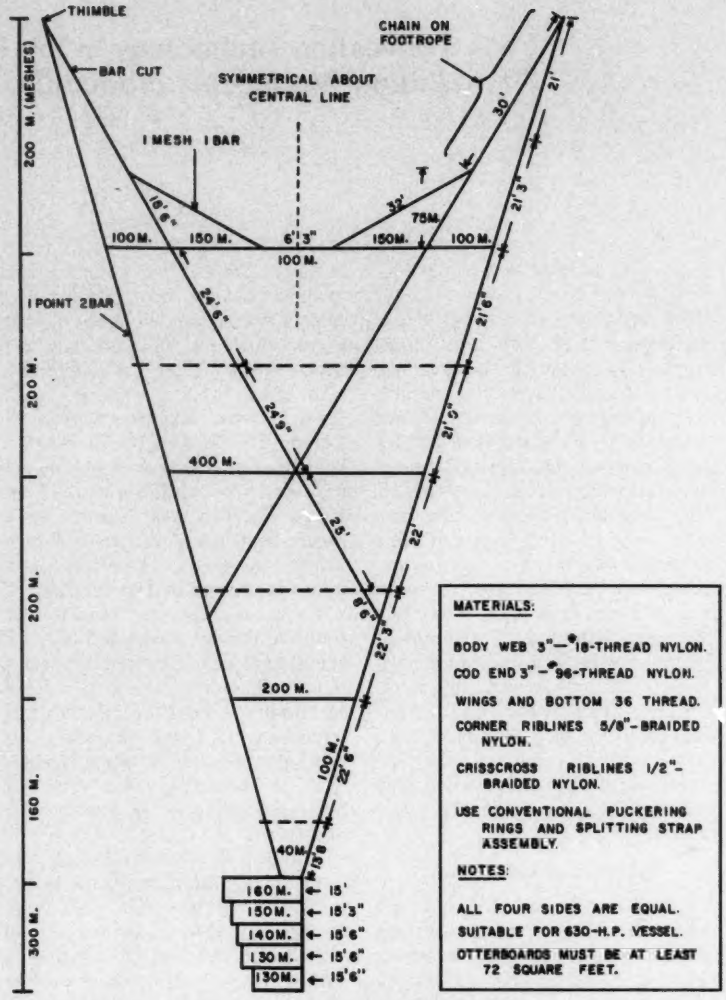


Figure 1.—Standard 18 Cobb pelagic trawl.

Figure 2 is a net diagram prepared by a Soviet fishing master illustrating the general configuration of the most common type of midwater trawl used by Soviet vessels at that time. It shows design characteristics intermediate between early midwater trawls such as the Cobb pelagic trawl and current trawl designs. Mesh sizes graduated down from 2,400 mm stretched measure in the wings through 1,600 mm, 1,200 mm, 800 mm, 400 mm, 200 mm, to 120 mm in the belly sections adjacent to the codend, which was of 60 mm mesh. The large meshes in the foward parts of the trawl "herded" the fish deeper into the trawl, which tapered gradually back to the

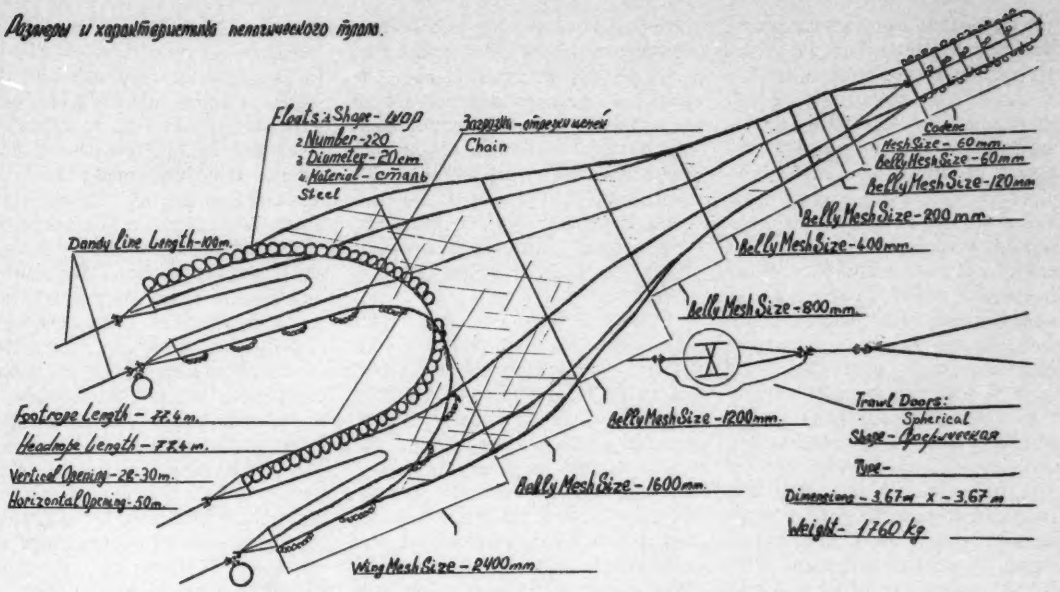


Figure 2. – Illustration of a U.S.S.R. midwater trawl prepared by a Soviet fishing master for a U.S. foreign fishery observer. The Russian legend reads: "Pelagic trawl dimensions and characteristics."

codend. As the fish moved deeper into the trawl, entering more and more confined spaces, the mesh sizes were reduced to enhance the herding effect, a necessary step to prevent panic escape reactions in the fish as they found themselves increasingly confined and crowded within the trawl. By using mesh sizes just small enough to elicit the herding response, and gradually reducing the mesh sizes only when necessary to sustain that response, it was possible to build trawls with the very large mouth openings necessary for capturing large quantities of fish while holding towing resistance down to an acceptable level. This strategy of taking advantage of fish behavior in the design of large, low-drag trawls is still being refined today.

Other design features were similar to some contemporary midwater trawls. The trawl was roughly rectangular in cross section, with abbreviated wings. The headrope and footrope were of equal length, 77.4 m, while the breastlines were 40 m long. Three hundred kilograms of chain were seized to the footrope to open it downwards, along with an 800 kg weight at each lower wingtip. Doors were round and concave for enhanced hydrodynamic efficiency. Acoustic-link netsondes, or depth sensors, were used to record trawl depth at the headrope and gauge the vertical opening of the trawl from the headrope to the footrope. Unlike more modern designs, floats were used to lift the headrope, and upper and lower bridle lengths were equal, 100 m from each wingtip to the door.

The next step in the development of whiting gear was introduced by the Polish fleet. Gear designers of the German Democratic Republic (East Germany) had developed large midwater trawls that employed longitudinal ropes in the wings and forward body sections instead of meshes (Rehme, 1973). These ropes led into meshes further back in the body of the trawl, which then graduated down as described above. The ropes served the same herding function as the large meshes in the earlier Soviet designs, while offering still less drag-inducing surface area. Thus, it was possible for the same vessels to fish still larger trawls, with improved fishing power. The Poles were the first to bring rope trawls into the whiting fishery, but the idea was quickly picked up by the Soviets and other Eastern Bloc fishing fleets, and rope trawls dominated the fishery by 1979.

Current Gear Types and Fishing Practices

Currently, the dominant Pacific whiting fishery in U.S. waters is the so-called "joint venture" fishery, wherein domestic catcher boats capture the fish and deliver them at sea to foreign-owned vessels for processing. The details of payment procedures, fleet organization, and disposition of the processed fish vary from operation to operation, but the mechanics of locating and harvesting and transferring the catch are similar.

Prior to 1978, the first year of

operation of the joint venture fishery, there was very little domestic fishing effort targeting on whiting other than the short-lived demonstration fishery described earlier. A few boats up and down the coast, of varying sizes and using a variety of trawl types, continued to catch relatively small quantities of whiting for delivery to shore-based processing plants where it was usually made into animal food. While the resource available to the domestic coastal draggers was ubiquitous and abundant, the volumes the processors would buy and the prices they would pay were low, so there was little impetus to develop efficient gear types or fishing procedures. Nonetheless, innovative fishermen experimented over the years with large midwater trawls of European design, pair trawling, and other measures. The coastal draggers, operating in this and other fisheries, gained experience with midwater trawling and refined their boats and gear.

With the advent of the joint-venture whiting fishery came an opportunity that the coastal draggers were ready to exploit, and they moved quickly. Even in the first year, the experienced Soviet whiting fishermen were impressed by the efficiency of the small U.S. catcher boats, and catches routinely exceeded the capacities of the factory ships' processing lines.

From the inception of the joint venture fisheries, the catcher boats have exclusively used one variation or another of the basic rope trawl design. Known as Polish rope trawls due to their introduction by the Polish fleet, the original design has been refined by domestic gear manufacturers to suit the needs of the joint-venture fisheries and is now a very efficient piece of gear. When they are "on the fish," joint-venture catcher boat skippers expect to catch between 1 and 3 tons of whiting per minute, depending on the size of the trawl used. Refinements have been made on a number of construction details, but perhaps the most important have been in the following areas: Length and mode of attachment of the ropes, proportions of the top and bottom sections versus the sides, and tapers employed in the body panels. The goals of these refinements are to maintain or increase the mouth openings of the trawls and the herding and containment efficiency by taking advantage of the behavior of the fish, while keeping drag to a minimum. Other vital considerations are durability of the trawl and ease of operation.

Figure 3 depicts a rope trawl design used in the 1981 joint venture whiting fishery. More recent designs differ somewhat from this to incorporate refinements, and designers are understandably reluctant to divulge the details of their latest advances, but this diagram illustrates the general characteristics of modern rope-trawl design. Gear builders typically offer a series of similar trawls, scaled up or down to match the towing capabilities of the vessel for which a particular trawl is intended.

One noteworthy feature of contemporary rope-trawl design is the virtual absence of floats. Rather than relying on floats to pull the headrope up away from the footrope, in these trawls the footrope is weighted with chain and detachable weights secured ahead of the ends of the footrope, which pull the footrope and lower panels downwards. To facilitate spreading, the upper and lower sweeplines are attached to the upper and lower corners of the doors, respectively, and the lower sweeplines are lengthened to allow the footrope to open down and still stay directly beneath the headrope. The only floats used on the trawl, excluding some floats sewed to the detachable codend, are found along the two top center ropes just behind the headrope where the netsonde is attached. These floats help to orient the trawl and netsonde during setting and haulback, minimizing tangles.

Rectangular, cambered, high aspect ratio midwater doors, also known as "Suberkrub" (FAO, 1974) doors, are the most common type by far in the joint venture fleet. While most Suberkrub doors are made of steel, some are of aluminum. The size and weight of the doors must be tailored to the towing capabilities of the vessel, as well as matched to the gear to be towed. Suberkrub doors possess a number of performance characteristics that have made them the standard for the fleet. Of the commonly used designs, they are the most efficient available in terms of spreading power versus drag. They can be quickly and easily "tuned" for different fishing conditions by changing such things as the towing point or the points of attachment for the lower sweeplines. For example, it might be useful when fishing around pinnacles to adjust the doors so that they will rise quickly, pulling up the net, when towing speed is increased. Other adjustments would make the doors become less sentitive to towing speed, or sink faster, or spread less if increased vertical openings were called for.

Perhaps the paramount feature uniquely characterizing the gear used in the joint venture fisheries is the detachable codend (Fig. 4). Instead of having the codend sewed permanently to the body of the trawl, as is usually done, a "zipper knot" similar to the knot used to close feed bags is used which allows full codends to be quickly detached from the rest of the trawl. At the end of the tow, the trawl is hauled back aboard until the front end of the codend has just been brought aboard, leaving the part containing the fish in the water aft of the boat. The codend is then detached. The open end of the codend is choked off with a nylon line and held on the catcher boat until, using a buoyed messenger line, a tow line from the processor boat has been brought over (Fig. 5) and the codend has been made fast to it. This done, the codend is released from the catcher boat (Fig. 6) and winched aboard the processor (Fig. 7), where the catch is spilled and processed. Meanwhile, empty codends may be transferred from the processor to the catcher boat, which then resumes fishing.

There is no such thing as a "standard" joint-venture catcher boat, as most of the participating vessels were

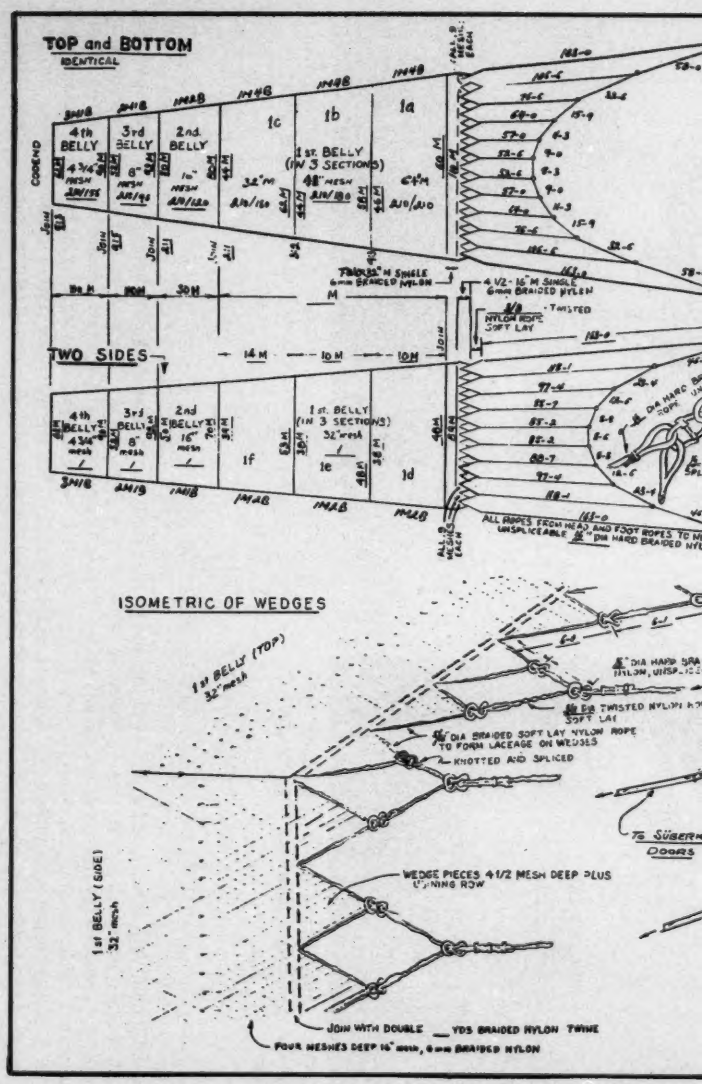
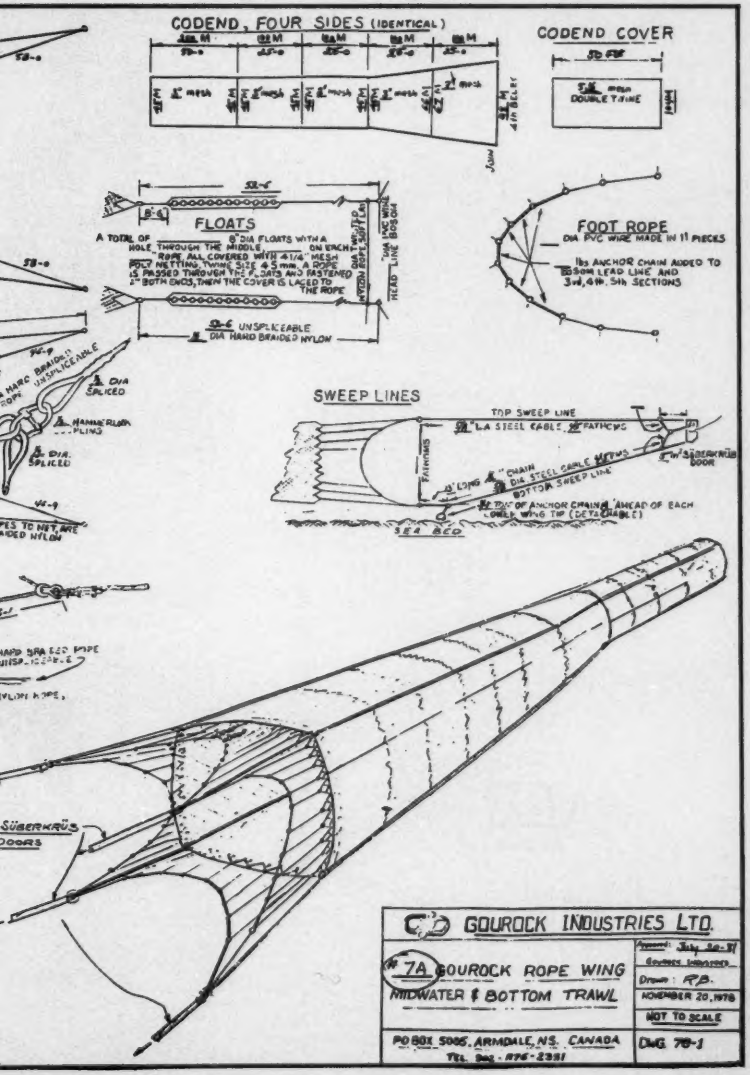


Figure 3.—Plan of a typical rope wing trawl used in the 1981 jo



981 joint venture whiting fishery by vessels of 700-1,000 horsepower.

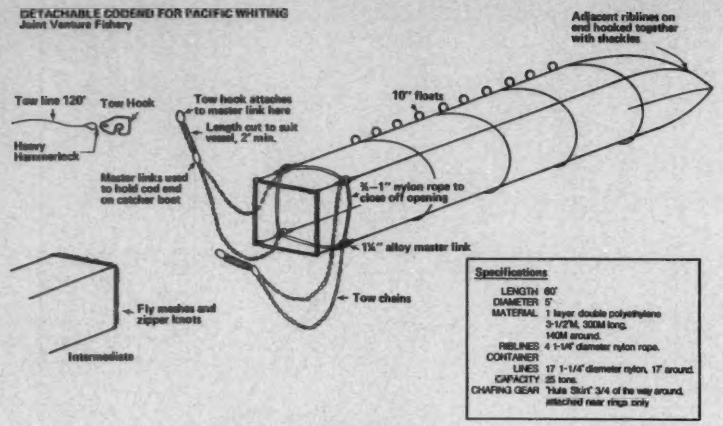

DETACHABLE CODEND FOR PACIFIC WHITING
Joint Venture Fishery
Adjacent riblines on end hooked together with shackles
Tow line 120'
Tow Hook
Tow hook attaches to master link here
Length cut to suit vessel, 2' min.
10" floats
Heavy Hammerlock
Master links used to hold cod end on catcher boat
⅝—1" nylon rope to close off opening
1¼" alloy master link
Tow chains
Fly meshes and zipper knots
Intermediate
Specifications
LENGTH 60'
DIAMETER 5'
MATERIAL 1 layer double polyethylene 3-1/2"M, 300M long, 140M around.
RIBLINES 4 1-1/4" diameter nylon rope.
CONTAINER LINES 17 1-1/4" diameter nylon, 17' around.
CAPACITY 25 tons.
CHAFING GEAR "Hula Skirt" 3/4 of the way around, attached near rings only

Figure 4.—Detachable codend details.

Figure 5.—Buoyed tow line being streamed back from a joint-venture processing ship to a catcher boat.

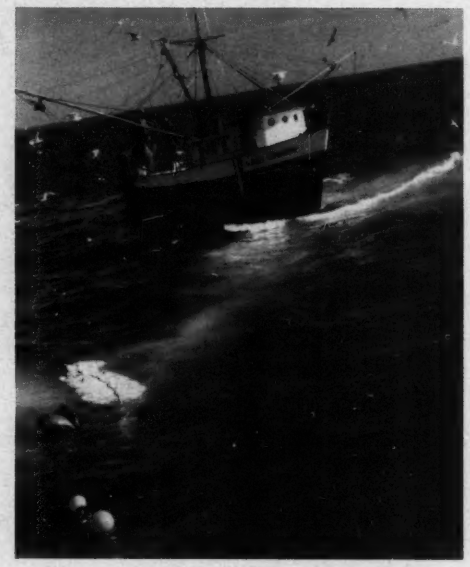


Figure 6.—Codend full of fish being towed from a catcher boat to a processing ship.

originally built with other fisheries in mind. Consequently, deck gear and layout vary considerably from boat to boat within the constraints laid down by the requirements of midwater trawling. Having said this, an attempt will be made to describe the most common features of a joint-venture boat. Many of the catcher boats were built for the coastal bottom-trawl fisheries, and are about 80 feet (24 m) long with a 24-foot (7 m) beam. A typical boat fishes its primary trawl from a net reel mounted just aft of the house. Spare trawls and/or empty codends may be stored on the after net reel(s), mounted above the deck on a stern gantry. Some kind of

Figure 7.—Full codend being winched up the ramp of the processing ship, a Soviet BMRT factory trawler. Note the "Suberkrub" trawl doors hanging at the stern, and the spherical trawl doors stacked on deck forward of the ramp area.

Figure 8.—The bridge of the *Colintino Rose II*, a typical modern joint-venture catcher boat. Note the numerous electronic aids visible here.

A-frame or boom arrangement facilitates handling the gear on deck, and accessory gilson winches, splitting winches, outhauls, deck cranes, catheads, etc., will be found in various combinations. Conventional trawl winches are most common, carrying warps of ⅝-⅞ inches (16-22 mm) in diameter, although some boats are installing the more advanced "constant-tension" winches of European design. Main engines of 750-1,000 horsepower are most common in the 75-90 foot (23-27 m) vessels, with more powerful engines found in some of the larger Alaska king crab vessels that have been converted to trawling. Kort nozzles, aftercoolers, and other means of boosting towing performance are being installed throughout the fleet, the goal being to pull the largest possible trawl that can be towed at 3 knots or more.

The joint-venture catcher boats rely heavily on electronic aids to maximize their catching efficiency (Fig. 8). Sonar systems of varying degrees of sophistication are used to locate schools of fish. Driving the boat over a selected school, the skipper uses the echosounder to get information on school depth, density, and composition. There is a trend toward increased use of color sounders because of the added ease of interpretation of the echo information. For even finer resolution of within-school density distributions an acoustic device known as a "memo-scope" may be employed. With the memo-scope, selected portions of individual echo pulses may be expanded and examined in detail, yielding information about target density within a fairly small area. Loran-C navigation systems provide precise positioning information, especially when coupled to an automatic plotter unit, either paper or video. Using a plotter it is easy to record the exact locations of promising fish traces while scouting for fish.

Once a specific school has been targeted and the gear has been set, electronic aids continue to guide the

fishing process. The echosounder indicates the approximate depth to which the trawl should be set in order to intercept the fish. The netsonde on the trawl provides immediate information on the trawl's performance and its position within the water column. Echoes from fish above or below the netsonde's headrope transducer allow the skipper to adjust the depth of the trawl for maximum catch, especially useful when the fish have moved between the time they were detected on the vessel's echosounder and the time the trawl arrives. Additionally, variations in the intensity of the fish traces passing below the headrope indicate the quantity of fish entering the trawl, an index of catch rate.

Wireless netsondes, which rely on an acoustic link to transmit information via a hydrophone mounted either on the ship's hull or a towed fin, are the most common type found in the joint venture fleet. The more expensive "third-wire" netsondes, using a wire from the netsonde to the ship for data transmission, are favored by some skippers because neither vessel maneuvers nor water conditions can disrupt the data link, and current third-wire systems can provide desirable additional information unavailable with current wireless systems. In particular, the catch-load indicators available as accessories with some third-wire systems have proven their value. With knowledge of the quantity of fish in the codend, the skipper can shorten or extend the tow to get a catch of the preferred size, usually 25-30 tons. Additionally, by comparing the rate at which the codend is filling up with the rate at which fish pass below the netsonde's headrope unit, the skipper can detect escape reactions among the fish within the trawl and alter his operations accordingly.

In addition to the equipment described above, joint venture boats carry the usual assortment of other navigation, communications, and safety gear, such as SSB, CB, and VHF radios, satellite navigation systems, weather facsimile receivers, and radars.

While the joint venture fishery is the dominant fishery for Pacific whiting, other fisheries do exist. Small-scale shore-based fisheries continue to operate up and down the coast, usually involving smaller, older vessels employing an assortment of trawl types. The whiting vessels delivering to processors in Oregon and California use rope trawls for the most part, with the exception of a few vessels using bottom trawls. Draggers involved in the Puget Sound, Wash., whiting fishery depart from this norm. One vessel uses a smaller version of the "2/3 Cobb pelagic trawl" described by Johnson and High (1970), with an 18.3 m (60-foot) headrope, 18.3 m breastlines, and an 18.3 m footrope. Two other fishermen use two-seam bottom trawls of their own design, incorporating 108 mm (4¼-inch) mesh in the forward panels and with a 21.3 m (70-foot) headrope and a 27.4 m (90-foot) footrope.

Recently joint-venture fisheries for whiting have gotten underway in Canadian waters. No preferred trawl type has yet emerged within this fleet, as a number of different modern midwater trawl designs are being employed. Otherwise, the vessels and fishing practices are similar in most respects to the U.S. joint-venture operations already described.

Summary

The harvesting technology in the Pacific whiting fishery is in a state of rapid evolution, particularly in the joint venture fisheries. As fast as improved trawls and electronic instruments become available and prove their worth, they are quickly adopted throughout the fleet. At present, most boats use recent versions of Polish rope trawls spread with Suberkrub pelagic doors. Catch rates between 1 and 3 tons per minute are relatively easy to attain with well-tuned gear.

Extensive use is made of sophisticated electronic aids. Sonars are used to locate schools of fish, and echosounders are used to gain additional information about school depth and density. Additional information on within-school density patterns can be obtained with memo-scopes and/or color sounders. Automatic plotters coupled to the ship's Loran-C systems are valuable for recording the locations of schools when scouting for fish. While fishing, netsondes of various kinds provide essential information on trawl position and catch rates.

Acknowledgments

A number of individuals and organizations made substantial contributions during the preparation of this report. Captains Carl Burlesci, A. Geiser, and Lyle Yeck gave generously of their time while describing their catcher vessels and their operational practices in the joint-venture fisheries. The Gourock Division of Wire Rope Industries, Ltd., furnished plans for a rope trawl, and Northeastern Trawl Systems, Inc., provided information from which the detachable codend illustration was drawn. Marine Resources Company and the NMFS Foreign Fisheries Observer Program provided other illustrative material. Dennis Lodge of Clatsop Community College, Astoria, Oreg., and Ben Jones and Fred Wathne of the NMFS Northwest and Alaska Fisheries Center, Seattle, Wash., reviewed the manuscript and made many helpful suggestions. Carol Hastings helped with the figures.

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Parasites as a Limiting Factor in Exploitation of Pacific Whiting, *Merluccius productus*

Z. KABATA and D. J. WHITAKER

Introduction

The parasite fauna of Pacific whiting, *Merluccius productus*, like that of most commercial fishes in the eastern North Pacific, have not been adequately studied. The extent of our knowledge is best exemplified by the fact that, while Margolis and Arthur (1979) listed 10 parasite species recorded for this fish in Canadian waters, a small-scale survey carried out fairly recently in the Strait of Georgia (Sankurathri et al., In press) augmented that list to 22 species. In view of the strong impact that some of these parasites exert on the Pacific whiting fishery, this lack of attention is regrettable.

The parasites of Pacific whiting on which attention has been focused recently belong to the protozoan phylum Myxosporea. Sankurathri (1977) described *Conispora renalis* from the renal tubules of the whiting in Georgia Strait. This species was found later to be identical with *Myxoproteus meridionalis* Evdokimova, 1977, discovered in the urinary bladder of *Merluccius hubbsi* Marini, 1933, on the Patagonian shelf. Evdokimova's (1977) description, chronologically before that of Sankurathri, was incorrect in placing that species in *Myxoproteus*. It was necessary to place it in *Conispora*, while retaining Evdokimova's original specific name. It is now known as *Conispora meridionalis* (Evdokimova, 1977) (Sankurathri et al., In press).

More important, however, are the parasites belonging to the genus *Kudoa* Meglitsch, 1947, which, because of their histozoic habits, are of direct concern to the fishing industry. Grabda and Grabda (1975), who examined whiting taken by the Polish fishing fleet off California, recorded two species of *Kudoa* which they found in the musculature: *Kudoa clupeidae* (Hahn, 1917) and *Kudoa rosenbuschi* (Gelormini, 1944). The former has never been previously found in the genus *Merluccius*, but the latter is known to occur in the muscle of *Merluccius hubbsi* on the Patagonian shelf. Kabata and Whitaker (1981) put the validity of these records in doubt, because of morphological differences and dissimilarity in the host-parasite relationships. However, further studies in Californian waters are needed to allow a definitive conclusion in this matter. According to Kabata and Whitaker (1981), the two species of *Kudoa* infecting Pacific whiting off North American shores are *Kudoa thyrsitis* (Gilchrist, 1924) and *Kudoa paniformis* (Kabata and Whitaker, 1981). This paper concerns these two species.

Morphology and Life Cycle of *Kudoa*

Only the spores have been described in detail for the two species of *Kudoa* parasitic in Pacific hake. *Kudoa thyrsitis* (Fig. 1A) is distinguished by stellate spores, with four valves of unequal sizes. The spores are subconical in lateral view, the posterior corners of the valves forming sharp processes. The surfaces of the valves are smooth and the suture lines very fine. The polar capsules are pyriform, of unequal sizes, one capsule being distinctly larger than the other three.

Kudoa paniformis (Fig. 1B) has spores subrectangular in polar view, with rounded valves and smooth surfaces. Suture lines are devoid of ridges and are often somewhat sinuous. Polar capsules are pyriform. Detailed descriptions and measurements of spores are given by Kabata and Whitaker (1981).

The spores of *Kudoa* are important not only as the best clues to the identity of the species; they also play a prominent role in the life cycle of these parasites. The spore is the stage that serves as the means of dispersal of the parasite and as the source of infection for new host individuals. Released from the musculature of dead fish, it must float in water and make contact with the fish it is to infect. The release could occur as the result of natural death of the host and subsequent decomposition. It is also likely that moribund fish would be disposed of by predators. The spores, with the digested remains of their host, would then be voided by the predator. Whatever the mode of release, being heavier than water, they gradually sink and are likely to descend to levels deeper than the habitat of their potential host. Kovaleva et al. (1979) pointed out that the distribution of the various *Kudoa* species in

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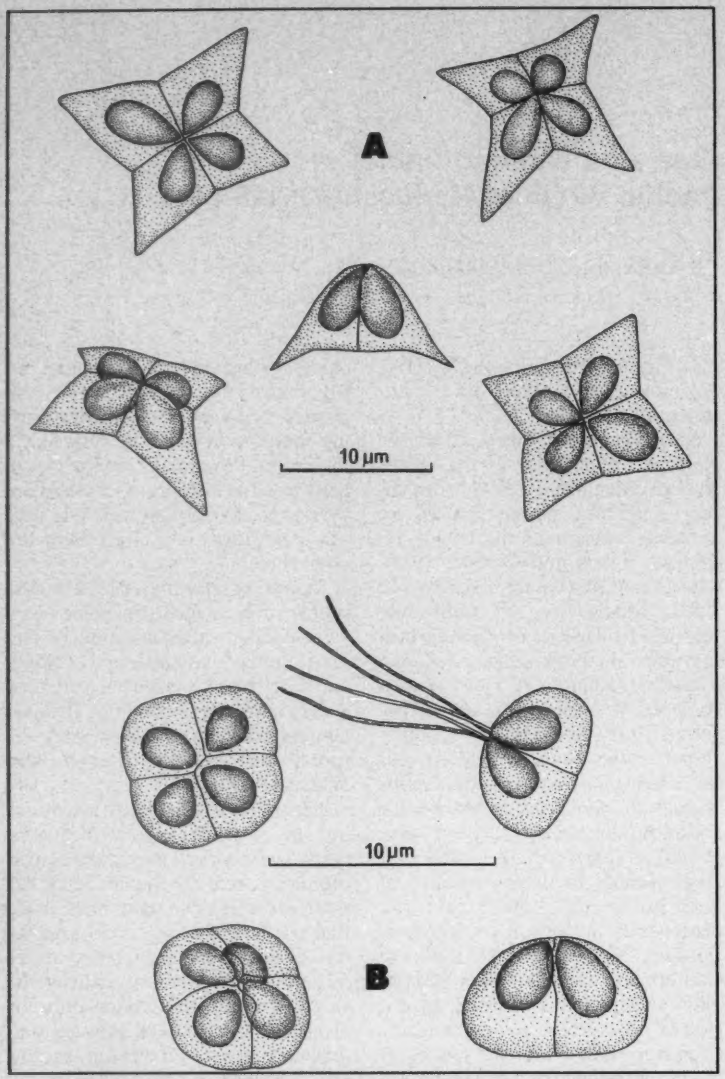

Figure 1.—Unfixed spores in lateral and anterior view: (A) *Kudoa thyrsitis*; (B) *Kudoa paniformis*. (From Kabata and Whitaker 1981).

the Atlantic Ocean coincided with areas of upwelling, in which the spores can be maintained by the ascending currents at the depths inhabited by their host species. The exceptions to this rule are provided by *Kudoa* parasitizing bottom-dwelling species of fish. (*Atheresthes stomias* provides an example of such a demersal host along the Pacific coast of North America.) The Pacific whiting is cannibalistic and is often taken with the remains of its conspecifics in the alimentary canal. The latter way of infection is more likely to deliver a concentrated dose of spores to the new host.

It is currently presumed that *Kudoa* reaches its target site within the host via the intestinal tract and the circulatory system, but evidence supporting this presumption is still circumstantial, at least for this particular myxosporean genus.

The earliest stage known in the life cycle of *Kudoa* parasitic in Pacific whiting is a large trophozoite filling a sometimes substantial portion of a muscle fiber. In some instances the entire fiber is filled by the parasite to the point of becoming visibly distended. Observation with the naked eye reveals these fibers, or pseudocysts, as white or black streaks. A new generation of spores develops within sporoblasts contained inside these relatively gigantic trophozoites.

The distribution of pseudocysts in an individual host is not uniform. There are no significant differences between the right and the left side of the fish, but the number of infected muscle fibers tends to diminish from the anterior end toward the tail of the fish. The area most heavily infected is the dorsal musculature immediately behind the head; the lightest infection is found in the caudal peduncle. In view of the life history of *Kudoa*, this type of distribution is not unexpected. The sporoplasms (the infective agents carried within the spore) are released in the intenstine, penetrate the gut wall, and enter the bloodstream. They are then carried by blood via the hepatic portal system, through the liver, heart, and gills, to the dorsal aorta. Along the latter they are transported in the posterior direction. The blood vessels branching off from the aorta near its origin have the greatest chance of receiving the protozoan intruder. The number of parasites dwindles with their transport towards the tail.

Effect of Infection on Muscle Tissue

Both species of *Kudoa* mentioned above penetrate individual muscle fibers. They do not appear to undergo

any division, once within these fibers. Judging from some very high intensities of infection, some division probably occurs after the sporoplasm enters the blood vessel. In consequence, a single sporoplasm could provide the means for infecting many muscle fibers. Within the confines of a fiber, the feeding stage (trophozoite) expands and its surface membrane develops countless irregular villosities. The normal structure of the fiber is disrupted, and its tissue gradually breaks up and is replaced by the parasite. The trophozoite gradually fills with spores of various stages of development. The parasite within the fiber is sufficiently isolated from the host to prevent its immediate defensive reaction. At this stage the term "pseudocyst" is properly applied to the infected fiber, to distinguish this condition from the true cysts which are much more disruptive to the tissues and are surrounded by connective tissue capsules deposited by the host. Each pseudocyst is a cylindrical, elongated structure, often apparent to the naked eye as a streak of color, distinguishing it from the surrounding, uninfected muscle fibers. The color of pseudocysts varies with the age of the infection. At the relatively early stage, when the trophozoite is still growing and filling with spores, the color of the fiber is opaque white. As the villosities of the trophozoites approach the sarcolemma of the muscle fiber, the enzymes produced by the parasite leak out and are detected by the host; the host's reaction becomes histologically evident. It consists of surrounding the infected fiber with histiocytes. Within the coating of these cells, the infected fiber gradually assumes a yellowish hue, passing into brown and eventually black. By a process as yet unknown the parasite is compressed, the spores progressively crumpled, and, in the end, destroyed. (Work on the reaction of whiting to *K. thyrsitis* is in progress.)

The three stages, from uninfected (N), through young, white pseudocyst (W), to old, black ones (B) are shown in Figure 2. In particularly heavy infections nearly 1,000 pseudocysts per

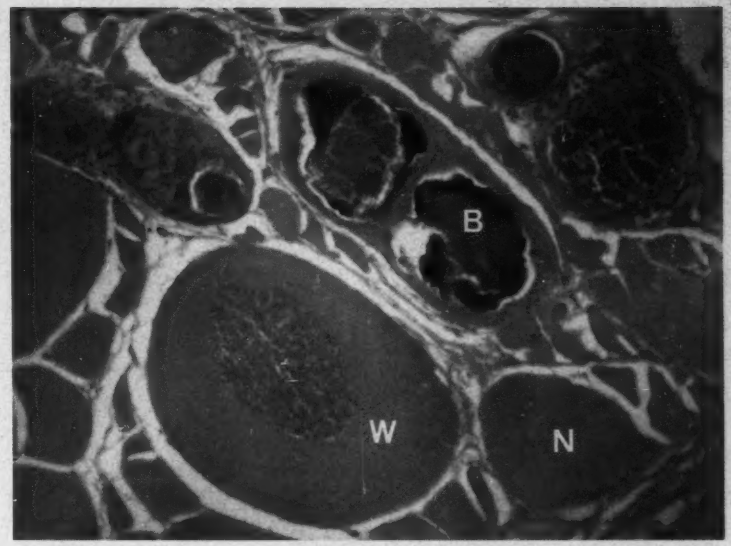

Figure 2.—Transverse section through musculature of hake, showing uninfected fibers (N); young, white pseudocysts (W); and old, black pseudocysts (B).

gram of muscle tissue have been found (Kabata and Whitaker, unpubl. data). The infected fibers obviously lose their contractility and can no longer participate in the locomotion of the fish. The fact that the fish, even when heavily infected, can still continue its locomotory activities, is understandable, when one takes into account that the white muscle, which constitutes the substrate of the parasite, is not extensively involved in the normal cruising movements. *Kudoa* has not been found in the dark muscle, the main natatory effector.

The infected fillet is streaked with distended, white or black (or both) fibers, depending on the intensity and age of the infection. Not unnaturally, its appearance markedly lowers the acceptance of the product by potential customers, even if infected fish is supplied to them in otherwise satisfactory condition. From the point of view of the fishing industry, however, much more important than any mechanical damage is the effect of the chemical substances produced by the parasite. As demonstrated by Patashnik et al. (1982), the substances in question are proteolytic enzymes. During the life of the fish, the excretory system is efficient enough to prevent the accumulation of the enzyme in quantities sufficient to result in serious damage to the muscle tissue. The death of the host has a twofold effect: It terminates the functioning of the excretory mechanisms, while, at the same time, the production of the enzyme continues unabated. Facing biochemical changes induced by the death of the host, the parasite brings its development to the final process of sporulation, and formation of protective spores, over a period of 8-12 hours (Willis, 1949). No longer removed from the site, the enzyme accumulates there, with consequences discussed by Nelson et al. (1985).

Tsuyuki et al. (1982) discovered two temperature optima for the proteolytic activity of the enzyme produced by *Kudoa*, one at 35-40°C (pH 3.8), the other at 55-60°C (pH 6.7). It is possible that these optima corre-

spond to the activities of two enzymes, produced by the two species of *Kudoa* examined. There are strong indications that the efffects these species exert on whiting differ in their magnitude. Although more work is required to arrive at definitive conclusions, it appears, in light of present evidence, that *K. thyrsitis* is less damaging to whiting flesh than *K. paniformis*. Some speculations on the reason for this difference are included below.

Prevalence and Intensity of Infection

In spite of its acknowledged importance to the fishing industry, the prevalence of the *Kudoa* infection of whiting has never been subjected to an adequate parasitological investigation. The work of Patashnik et al. (1982) is an example of the difficulties facing workers investigating a parasitological problem without appropriate input from parasitologists. Although Patashnik and his colleagues were aware of the existence of two species of *Kudoa* (which were referred to as "small" and "large" *Kudoa*), the infection was treated as a single phenomenon. Having examined samples of 10-15 fish, they found that the combined prevalence ranged from 20 to 40 percent. These figures are at odds with those obtained by Kabata and Whitaker (1981), who found much higher prevalence of *Kudoa*. In a sample of 322 fish taken in a single haul off the southwest coast of Vancouver I. in September 1980, the prevalence of infection was 89.5 percent. *K. thyrsitis* was found in 32.2 percent and *K. paniformis* in 38.8 percent of the fish examined. A further 18.3 percent were infected with both species. In the Strait of Georgia, where 100 fish were examined, only *K. thyrsitis* was found, parasitizing 99 percent of the sample. It is possible that a systematic survey will discover a middle ground between these two sets of data. However, the prevalence figures of Patashnik et al. (1982) are probably too low. This is suggested by the data obtained recently (Kabata and Whitaker, unpubl. data) from examination of a small sample (35 fish) collected off the mouth of Columbia River in June 1982. The overall prevalence was 94.3 percent with *K. thyrsitis* present in 42.9 percent of the sample, *K. paniformis* in 17 percent, and mixed infection in 34.3 percent.

The estimate of intensity of protozoan infections is notoriously difficult, exact counts being impossible for obvious reasons. It is fairly generally accepted that categorizing of infection into light, medium, and heavy is sufficient to express intensity. Kabata and Whitaker (1981) used this scale, having arbitrarily defined light as the presence of <20 pseudocysts, medium as 21-100, and heavy as >100 per area. Counts of pseudocysts were made under a dissection microscope, the entire fillet being macerated in the process. A fillet was divided into six areas, horizontally by the lateral line and vertically by two lines marking off three parts of equal length. Patashnik et al. (1982) estimated the intensity of infection by "visual observation," presumably without any optical aids. Their scale of intensity was 0-5, with 0 denoting absence of observable parasites. It was based "on the percent of the area affected," 1 = trace (up to 5 percent); 2 = slight (5-20 percent); 3 = moderate (20-30 percent); 4 = severe (30-50 percent); 5= excessive (>50 percent). The precise definition of the "area affected" was not provided. The present authors, in work now in progress, have resorted to a more quantitative determination of the intensity of infection. They are using a number of pseudocysts (nearly or completely equivalent to the number of trophozoites) per gram of muscle tissue in six areas defined above.

Neither of the two sets of observations described above can be said to reflect the true prevalence and intensity of *Kudoa* in whiting flesh. As mentioned, the presence of this parasite in the fish is not easily detectable until the development of pseudocysts. (Stages prior to cyst formation have not yet been detected.) Some period, of still unknown duration, must elapse between the time of entry of the parasite and the formation of these aggregates of spores. That period must be characterized by the intensive activity of the parasite, passing through its successive stages of development. The existence of a "hidden increment" of infection can be confidently postulated. The size of that increment cannot be assessed on the basis of data available. Its assessment is, however, necessary, if the true effects of *Kudoa* on the flesh are to be correctly understood. Some ambiguous results of investigation of these effects are almost certainly due to the fact that of any two apparently uninfected fish one might harbour *Kudoa* in its "hidden" stage. Proposed future studies of the *Kudoa* problem must, therefore, include investigation of the origin and early stage of infection.

The distribution of the two *Kudoa* species and their effects offer grounds for some interesting speculations. *K. thyrsitis*, the less harmful species, is also the more widespread. It has been reported from several species of fish as far from the American Pacific as Australia and South Africa. In the latter part of the world it was recorded in *Merluccius capensis* by Priebe (1967). In the area inhabited by the Pacific whiting it has been found also in walleye pollock, *Theragra chalcogramma*, and some flatfish species. Both the distribution and the host range suggest an "old" species, well adjusted to its hosts and, consequently, not excessively harmful. In contrast, *K. paniformis*, widespread in the offshore whiting population, appears to be a relative newcomer. It does not occur in the Georgia Strait whiting stock or in a small inshore stock on the west coast of Vancouver I., both isolated from the main offshore population. It has not been found in any other fish species. These facts suggest that *K. paniformis* infected whiting subsequent to the separation of these stocks. As a "new" parasite, it has not yet attained a stable equilibrium with its host and is, therefore, much more virulent in its effects.

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Preservation and Processing Characteristics of Pacific Whiting, *Merluccius productus*

RICHARD W. NELSON, HAROLD J. BARNETT, and GEORGE KUDO

Introduction

The Pacific whiting, *Merluccius productus*, has been the object of considerable interest and research for nearly 20 years. Population estimates made in the early 1960's showed that Pacific whiting was one of the most abundant species of commercially harvestable fish off Oregon and Washington (Alverson et al., 1964). Although less abundant than off the coast, Pacific whiting are also found in the inland waters of Washington and Canada where they are commercially fished for domestic markets.[1] The species has been evaluated for potential use in traditional product forms such as fillets (Dassow et al., 1970) and as animal feed (Berg, 1970; Stout et al., 1970) as well as for the production of fish protein concentrate (Havighorst, 1971). Despite these efforts, Pacific whiting has not gained wide acceptance and remains an underutilized species in the domestic fisheries.

The lack of domestic utilization of Pacific whiting (especially ocean caught) can be attributed to several factors that relate to the properties of the fish and to economics. The major impediment to further commercial development of Pacific whiting is soft texture in the flesh of many individual fish caused by a microscopic parasite Myxosporea. Details of the parasite infection have been previously reported by Dassow et al. (1970), Kabata and Whitaker (1981), and Tsuyuki et al. (1982) and are the subject of a separate paper in this issue of the *Marine Fisheries Review* (Kabata and Whitaker (1985)). The parasite infection results in a high enzyme activity in the tissue causing rapid softening dependent on degree of infection, pH, temperature, and time. Since these factors vary significantly between fish and fish catches, it is understandable that confusion about Pacific whiting quality and acceptability is common. Unfortunately, the infected fish are not easy to cull out during processing because the infected tissue is not always visually obvious. The chemical, physical, and biological properties that are important to the future use of the species are discussed below.

Proximate Chemical Composition

The proximate chemical composition of Pacific whiting was analyzed at the Utilization Research Division, Northwest and Alaska Fisheries Center (NWAFC), Seattle, Wash., from 1964 to 1966 (Patashnik et al., 1970). The results of these analyses will be summarized here.

Pacific whiting is typical of white-fleshed fish. The protein content of the flesh ranges from 14 to 16 percent and the oil content ranges from 0.5 to 3.8 percent. Ocean whiting and Puget Sound whiting are apparently separate stocks and differ slightly in composition. Seasonal differences are also common. Tables 1-4 illustrate these variations.

Ocean Whiting

Tables 1 and 2 present average proximate composition values for ocean-caught whole whiting, edible fillets, and waste, and the range of variation for their average values. Whiting caught during the spring and early summer of 1964 and 1965 (March-July) had low fat contents of about 1.5-3.5 percent (Table 1). Subsequent composition data obtained from early season catches during 1966 were similar in content to composition data obtained from whiting caught in the early summers of 1964 and 1965. In contrast, whiting sampled during the falls of 1964-66 (September-November) had high fat contents of about 4-6 percent. The protein content, on the other hand, showed less seasonal variability. In 1964-66, the protein content was 13.4-15.0 percent during March-July periods, 14.4-15.6 percent during September-November periods. The ash content for the same periods was relatively constant at about 3.0 percent. The high moisture content during the spring and early summer was offset by the low total fat and protein contents.

The average values for moisture, protein, fat, and ash in Table 2 may be considered to reflect the average composition of whiting harvested during the months of May to November. The ranges in composition value may be considered the likely limits of

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variation in composition of the whiting during this same period. In Table 2, we note that the waste portion in comparison with the edible portion has a lower moisture and protein content and a substantially higher fat content.

Puget Sound Whiting

Tables 3 and 4 show the average chemical composition of Puget Sound whiting and the variation in average values for a year. The seasonal trends previously noted for whole ocean whiting were similarly apparent for Puget Sound whiting but were slightly out of phase. The fat content of whole whiting was highest from October 1965 through January 1966 and ranged from 6.4 to 7.4 percent; moderate from February through April 1966, 4.5-7.0 percent; and lowest from May to July, 2.5-5.0 percent. The average fat content of Puget Sound whiting was higher than that of ocean whiting, being 76 percent higher in the whole fish (5.7 percent vs. 3.3 percent), 56 percent higher in the fillets (2.5 percent vs. 1.6 percent), and 69 percent higher in the waste portion (6.4 percent vs. 3.8 percent).

The variation in protein content appeared to be related to the spawning cycle. The protein content was 13.6-14.7 percent from January through March. By April, the protein content dropped to 12.3-13.4 percent due to spawning. During May, protein increased from 13.2 to 14.9 percent, and by July, the protein had increased to 16.1 percent. By November and December, as the fat reached its maximum. protein dropped again to the 13.8-14.9 percent range noted early in the year.

Because the liver is known to be high in fat at certain times of the year, we analyzed male and female livers. For the period January through May and during October, the average fat content of female livers was 44 percent (33-49 percent) and that of male livers was 58 percent (34-68 percent). Male livers averaged 31 percent higher in fat than female livers. The liver generally is about 5-7 percent of the body weight so it represents a major contribution to the fat content of the whole fish.

The flesh quality of the Puget Sound whiting is superior to that of the offshore ocean whiting mainly because the abnormal (mushy) texture

Table 1.—Seasonal variation in proximate composition of whole Pacific whiting from coastal waters of Washington and Oregon, 1964-65[1].

Year and season	Proximate composition (%)			
	Moisture	Protein	Fat	Ash
1964				
Spring	81.4 ± 1.41[2]	14.3 ± 1.03	1.6 ± 0.21	3.2 ± 0.45
Summer-Fall	78.2 ± 1.78	15.2 ± 0.34	5.0 ± 0.73	2.9 ± 0.11
1965				
Spring	80.7 ± 0.80	14.0 ± 0.61	2.3 ± 0.42	3.2 ± 0.15

[1]These diets are season averages based on 14 samples of about 12 fish per sample (Dyer et. al., 1966).
[2]Mean ± standard deviation.

Table 2.—Proximate composition and potassium and sodium contents of edible fillets and waste portion of Pacific whiting from coastal waters of Washington, Oregon, and California, 1964-66[1].

Item	Moisture (%)		Protein (%)		Fat (%)	
	Fillets	Waste	Fillets	Waste	Fillets	Waste
Average	81.5 ± 1.29[2]	79.1 ± 2.05	16.5 ± 0.87	14.4 ± 0.64	1.6 ± 0.74	3.5 ± 1.76
Range	79.4-84.0	75.3-83.4	14.0-17.8	12.7-15.5	0.5-3.1	14.0-7.5

Item	Ash (%)		Potassium (%)		Sodium (%)	
	Fillets	Waste	Fillets	Waste	Fillets	Waste
Average	1.1 ± 0.18	3.8 ± 0.13	385 ± 44.4	269 ± 23.9	77 ± 18.6	173 ± 35.0
Range	0.5-1.5	2.3-4.7	335-470	237-304	51-103	135-228

[1]Composition data represent the average of 30 samples of about 12 fish per sample taken from January 1964 through October 1966. The potassium and sodium data represent 7 samples taken during 1964.
[2]Mean ± standard deviation.

Table 3.—Proximate composition of whole Pacific whiting from Puget Sound, 1965-66[1].

Item	Proximate composition (%)				Fish length (in.)	Fish weight (oz.)
	Moisture	Protein	Fat	Ash		
Average	77.9 ± 1.60[2]	14.0 ± 0.86	5.7 ± 1.34	3.0 ± 0.61	14.2	13.7
Range	75.1 ± 80.8	12.3-16.1	2.6-7.4	2.4-5.2	9.8-25.6	3.5-64.6

[1]Composition data are based on 19 samples of about 25 fish per sample taken during July 1965 to October 1966. Samples were largely from Port Susan and Saratoga Passage but also from Carr Inlet and Hood Canal and off Everett and LaConnor.
[2]Mean ± standard deviation.

Table 4.—Proximate composition of the edible fillets and waste parts of Pacific whiting from Puget Sound, 1965-66[1].

Item	Moisture (%)		Protein (%)		Fat (%)		Ash (%)	
	Fillets	Waste	Fillets	Waste	Fillets	Waste	Fillets	Waste
Average	81.3 ± 0.78[2]	78.5 ± 3.06	16.1 ± 0.95	13.7 ± 0.89	2.5 ± 0.85	6.4 ± 2.11	1.1 ± 0.19	3.8 ± 0.83
Range	80.2-83.1	72.6-82.7	14.0-18.7	11.7-15.3	1.2-3.8	1.6-9.8	0.9-1.7	3.1-7.0

[1]Composition data are based on 19 samples of about 25 fish per sample taken during July 1965 to October 1966. Samples were largely from Port Susan and Saratoga Passage but also from Carr Inlet and Hood Canal and off Everett and LaConnor.
[2]Mean ± standard deviation.

frequently found in ocean whiting is a relatively minor problem with the Puget Sound whiting so it can be more readily used in food-type products.

The average protein composition of the ocean whiting fillets was about 16.5 percent and that of the Puget Sound whiting fillets about 16.1 percent, making them both excellent food fish from a nutritional standpoint. Once the abnormal textural condition is completely resolved, whiting will have great demand as a high-quality food fish. The abnormal texture does not affect the availability of its high protein.

Sensory Properties

The sensory properties of any food product are extremely important in determining the acceptability and value of the product to the consumer. One of the major considerations in attempting to utilize Pacific whiting has been color, odor, flavor, and texture of the flesh. Texture is especially important in evaluating Pacific whiting as it is a major factor in determining the marketability.

Color

Athough color of the raw flesh varies from an off-white to pink, it is within the normal range of color found in the various Pacific coast species that are now filleted and marketed.

Odor

The raw flesh has a neutral odor typical of white-fleshed fish. As is common with most fish, Pacific whiting must be refrigerated immediately on landing aboard the vessel to avoid the development of strong odors on the skin.

Flavor

Very fresh whiting that is properly cooked has a bland flavor that consumers consider desirable. For many types of frozen prepared foods, such as precooked breaded fillets, this mild flavor permits modification with small amounts of additives.

Texture

In our preliminary evaluation of the potential use of whiting, fishermen and processors commented unfavorably on the soft, sometimes mushy texture of whiting. Our first concern was to determine the normal texture of fresh whiting, and then evaluate the problem of the abnormal mushy texture.

Normal Texture

The normal texture of whiting flesh is moist and tender but not mushy. Most testers find it quite similar to that of Dover sole, *Microstomus pacificus,* and English sole, *Parophrys vetulus.*

Abnormal Texture

In our investigation, we noted a high incidence of abnormal texture in cooked samples of whiting caught off the coasts of Washington and Oregon. This texture adversely affected the acceptability of the whiting as food. We observed that the mushy condition of cooked whiting was associated with a microscopic myxosporean parasite, *Kudoa* sp., in the muscle, similar to that reported in whiting and other fish species by Willis (1949), Fletcher et al. (1951). Patashnik and Groninger (1964), and more recently by Kabata and Whitaker (1981).

Impact of the Kudoa Parasite on Texture

Research reported by Kabata and Whitaker (1981) showed that two species of *Kudoa* infect Pacific whiting and that one of the two, *Kudoa paniformis,* is significantly more prevalent in the ocean whiting. Further, this species has more of an impact on the tissue. This explains why the Pacific whiting from the ocean fishery has softer texture than Pacific whiting from Puget Sound or Georgia Strait. The Pacific whiting from these inside waters is infected with *Kudoa thyrsitis,* which has less effect on texture.

The muscle portions seriously infected with the myxosporean parasite exhibit proteolysis of the tissue with accompanying liquefaction and mushiness. Similar observations were made by Tsuyuki et al. (1982) in research describing the relationship between acid and neutral protease activity in Pacific whiting muscle infected with *Kudoa* sp. parasites and the occurrence of soft or mushy texture. In some samples of fresh whiting, we found levels of proteolytic activity up to 14 times greater than those in normal-textured, uninfected controls. Research reported by Miller and Spinelli (1982) indicated that in addition to temperature control, the proteolytic enzyme in Pacific whiting could also be inactivated with chemical inhibitors permitted in human food systems. The texture of heavily parasitized whiting was almost always abnormal and mushy, but that of slightly parasitized whiting was frequently normal. Usually, the moderately parasitized condition did not significantly affect the proximate composition of whiting. However, in those extreme cases in which we could see the flesh had deteriorated, the proximate composition appeared to be significantly altered. For example, the muscle from a single excessively parasitized whiting taken from Puget Sound was 11.1 percent protein in contrast to an average of 16.1 percent and low value of 14.0 percent protein for all samples of Puget Sound whiting.

Parasite Significance

Although *Kudoa* sp. parasites are found in Pacific whiting, they are also common in certain species of marketed fish in other parts of the world (Willis, 1949). In studies by the National Marine Fisheries Service (NMFS) and others, the incidence of the parasite was found to vary on average from 20 to 40 percent in a sample, but 100 percent of the whiting have been infected in some samples; the degree of infection depended on the area of the catch and the size of the fish. From a commercial standpoint, a high incidence of infestation

in a catch would preclude its use for fresh or frozen fillets, owing to the probable mushy texture. At levels of low incidence, fillets of good quality can be produced with appropriate handling and inspection to eliminate any abnormal fillets.

There is no evidence that the Myxosporea can cause illness or infection in man. No health problems related to these organisms have been reported from areas, such as Japan, where raw marine fish are consumed; cooking readily destroys the organism if it is present in the fish muscle. Our main concern is the relationship of the organism to the textural quality and aesthetic acceptability of the fresh and frozen whiting products.

Table 5.—Comparison of sensory texture[1] of Pacific whiting frozen in dry ice, sectioned[2], and after 1-2 days of additional storage at 34°F refrozen and slow-[3] or fast-cooked.[4]

Vessel treatment	Texture scale	Average ratings in each texture category: Frozen control, Slow cooked No.	%	Frozen control, Fast cooked No.	%	Thawed: 1 day @ 34°F and refrozen, Slow cooked No.	%	Thawed: 1 day @ 34°F and refrozen, Fast cooked No.	%	Thawed: 2 days @ 34°F and refrozen, Slow cooked No.	%	Thawed: 2 days @ 34°F and refrozen, Fast cooked No.	%
Whiting frozen in dry ice	5 Normal	22	49	44	98	24	53	36	80	21	47	35	78
	4 Normal	21	47	1	2	10	22	7	16	13	29	5	11
	3 Soft	0	0	0	0	6	13	2	4	6	13	4	9
	2 Overly soft	1	2	0	0	3	7	0	0	3	7	1	2
	1 Mushy	1	2	0	0	2	4	0	0	2	4	0	0

[1]Average texture is indicated for each fish. Where over 25 percent of the fish sample had a 1 or 2 texture, the entire fish was rated 1 or 2. The texture of the fast-cooked, battered-and-breaded, deep-fried product was graded on the basis of the fish alone after removing the breading.
[2]Each whiting was cut into $^3/_4$-inch slices from nape to tail and sequentially placed into six treatment groups as indicated on the table. The slow- and fast-cooked comparisons of texture represent adjacent slices from three to five sections from nape to tail for each fish.
[3]Slow-cooked by baking in an oven at 400°F.
[4]Fast-cooked by frying in vegetable oil at 385°F (deep-fat).

Effect of Cooking Method on Texture

Because the soft texture of the cooked flesh of Pacific whiting is caused by the proteolysis of the muscle infected with the myxosporea parasite, the method of cooking will greatly influence texture. Since the proteolytic enzyme is eventually destroyed by heat, the rate of heating has a direct relationship on the texture of the cooked fillets that are infected with the *Kudoa* organism. The relatively slow methods of cooking, such as baking, broiling, or steaming, raise the temperature of the flesh to the optimum temperature range of the proteolytic enzymes associated with the parasite for a sufficient length of time to permit the enzyme to soften or liquefy the fish flesh before the cooking temperature rises to the point of enzyme inactivation. Rapid cooking methods, such as frying in deep fat at temperatures between 375°F and 400°F, shorten the interval between the temperature of maximum enzyme activity and inactivation of the enzyme and result in fillets with considerably better texture than do the slower methods of cooking. In one sampling of 76 whiting landed at Charleston, Oreg., fillet portions from 37 fish (48.7 percent) were mushy when baked, but only 4 portions of the 76 fish (5.3 percent) were mushy when deep fried. In another sampling of 378 whiting caught off the mouth of the Columbia River, portions of 25 fish (6.6 percent) were mushy when baked; but portions from all 378 fish were acceptable in texture when deep fried. Thus, it is essential to use rapid methods of cooking to minimize the incidence of mushy/pasty texture in the cooked flesh.

Effect of Preservation Method on Texture

A major concern of fishermen and processors contemplating participation in a whiting fishery has been the storage requirements to avoid texture degradation. Research conducted by the Utilization Research Division (NWAFC) has shown that rapid chilling following landing plus maintenance of temperature between 29°F and 32°F is important for minimizing texture problems. However, the degree to which soft texture occurs is largely a reflection of the degree of infestation of *Kudoa* rather than of temperature and time of holding. The results of several studies relating to method and time of holding are presented here to illustrate these observations.

Dry Ice

To evalutate the texture when cooked, whiting were frozen in dry ice and cooked immediately (control) or thawed and held for 1 and 2 days at 34°F, then slow or fast cooked (experimental group). Texture distribution, as determined by taste panel evaluations, is summarized in Table 5. Each fish was cut into six treatment groups according to the sampling sequence of Figure 1. When slow cooked (baked at 400°F) from the frozen state, 4 percent of the control samples were overly soft or mushy. When fast cooked (deep fried at 385°F with breading), 100 percent of

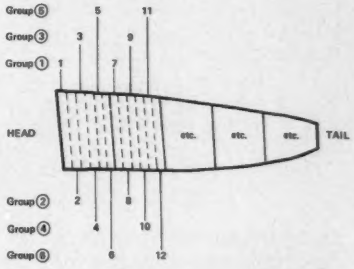

Figure 1.—Sampling sequence for dry-ice frozen and superchilled plate frozen whole Pacific whiting (18 to 30 $^3/_4$-inch slices), sequentially placed into 6 treatment groups of 3-5 slices per whiting per treatment.

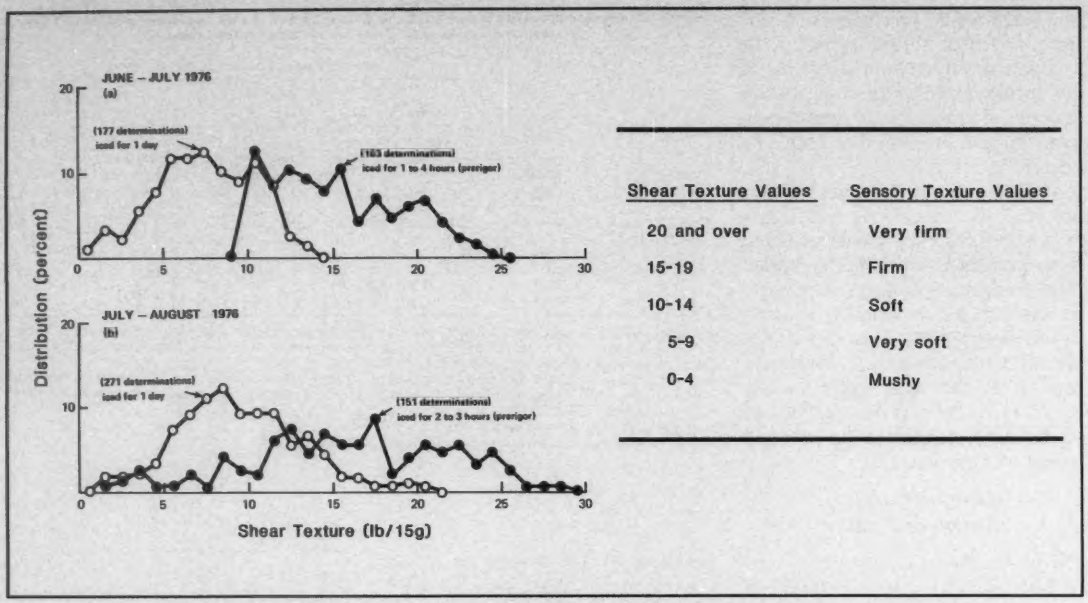

Figure 2.—Comparison of shear texture of steam-cooked fillets from Pacific whiting held iced prior to filleting and freezing for (a) 1-4 hours (prerigor) vs. 1 day and (b) 2-3 hours (prerigor) vs. 1 day (M/V *Willapa Bay*, 25 miles off Willapa Bay, Wash.). Shear texture values correspond to sensory texture ratings as shown in box (above right).

the control samples had a normal texture. When thawed and held for 1 day at 34°F, refrozen, and slow cooked, the texture of 11 percent of the whiting samples was unacceptably soft or mushy. But, when fast cooked, all these samples were acceptable. When samples were thawed and held for 2 days at 34°F., refrozen, and baked, 11 percent were observed to be soft textured. However, when fast cooked, only 2 percent were overly soft on the basis of the fish with the breading removed; evaluated with the crisp breading left on, the soft texture was not apparent and the product was considered acceptable. Thus, in spite of the predisposition of 11 percent of the frozen, thawed, and refrozen fish to have overly soft/mushy textures, the problem is largely overcome by fast cooking.

Storage in Ice

Experiments were conducted to determine how texture is affected by holding Pacific whiting on ice for various time periods prior to processing and freezing. Texture was measured using a shear-texture instrument developed at the laboratory (Dassow et al., 1962). The instrument consists of a hydraulically driven set of 5 movable and 6 fixed precision-ground blades that form a shear jaw. When actuated, the movable shear blades cut the sample and indicate the hydraulic force required. Samples of Pacific whiting obtained from several West Coast locations were held on ice for time periods of 1-8 hours and compared with fish held 1-3 days prior to freezing. The results show that longer holding on ice will cause more fish to have soft texture. However, there will be considerable overlap in texture values and some lots held short time periods will have a high incidence of soft texture. In Figures 2 and 3, comparative data have been objectively quantified using shear texture as a criterion. In replicate experiments (Fig. 2), whiting was held in ice for 1-4 hours, 2-3 hours (prerigor), and 1 day (24 hours), filleted, frozen, and steam cooked. The shear texture of the three groups was then compared, with a value of 0-9 being considered overly soft. In both tests, the steam-cooked fillets from whiting held for 1 day showed a significantly greater tendency to have mushy to overly soft-textured flesh than either the 1-to 4-hour test group (virtually none) or the 2- to 3-hour group (very little). In the third comparison (Fig. 3), in which whiting caught from two widely separated areas were held in ice for 5-8 hours vs. 2-3 days, we unexpectedly observed a high incidence of samples in the soft-to-mushy range when steamed or slow cooked.

These results suggest that high proteolytic activity in musculature of Pacific whiting may manifest itself shortly after capture and is very much apparent even in well-handled, 1-day-

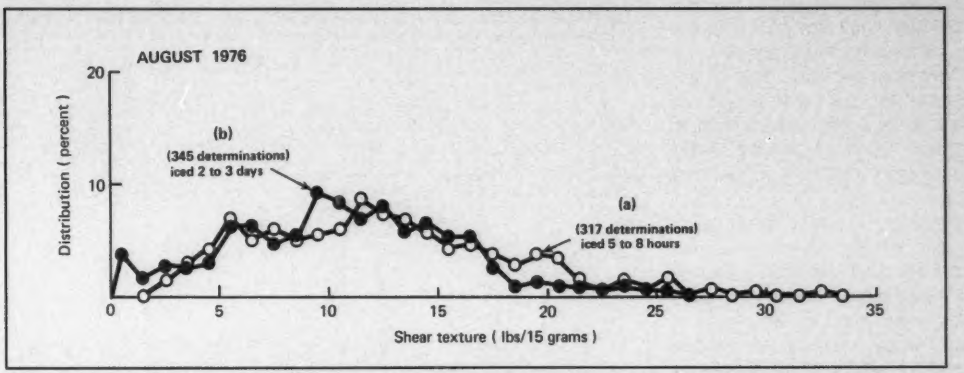

Figure 3.—Comparison of shear texture of steam-cooked fillets from Pacific whiting from two widely separated geographical areas held iced prior to filleting and freezing for (a) 5-8 hours (commercial vessel off Eureka, Calif.) vs. (b) 2-3 days (M/V *Willapa*, 25 miles off Vancouver Island, B.C.). Shear texture values correspond to sensory texture ratings as shown in Figure 2.

iced fish, when slow or steam cooked at 212°F. However, because of a wide range of textures in the slow-cooked product, some of the whiting have a rockfish-like texture with shear readings reaching 25-33 pounds/15 g.

Slush Ice and Ambient Temperature

During the summer of 1977, two tests were run aboard a commercial trawler to compare, by taste panel evaluation, the effect on texture of holding whole whiting for 6 hours on deck at ambient temperature and holding for 4 hours in slush ice. In the first test, using 25 fish in each treatment, a taste panel found that all of the fillets from the fish held in slush ice had an acceptable texture when baked, but 8 percent of the fish that were held at ambient temperature became mushy. In the second test, about 200 fish were treated in each manner. Surprisingly, the taste panel found that 13 percent of the fillets from the fish that were placed in slush ice immediately after landing had a mushy texture when oven baked, while 15.4 percent of those held at ambient temperature for 4 hours were mushy. However, the rapidly chilled fish had firmer textures and thus were easier to handle during machine filleting and skinning—a definite advantage.

But why the apparent large difference in percentage of mushy textured fish between the small-scale experiment and this larger experiment? The most probable reason for the difference in the results of the two tests lies in the levels of protozoan infection. In the first test, the whiting had a 28 percent level of infection with *Kudoa* cysts. In the second test, 59.3 percent of the fillets were infected with white *Kudoa* cysts. Variation in infection intensity within the individual fillets and from one fish sample to another appears to be the major factor that is responsible for variable texture. These natural variations in the protozoan level determine the postmortem proteolytic level and are most likely responsible for the inconsistent results in replicate experiments.

Collaborative tests on whiting preservation and quality were conducted aboard the Polish research vessel *Profesor Siedlicki* in the summer of 1977. With whiting taken from a trawl catch off northern California, the tests showed the level of proteolytic activity in whiting muscle to be independent of the time of storage both in slush ice through a 60-hour test period and at ambient temperatures (55°-64°F) through a 36-hour test period. The proteolytic activity and the texture changes were again determined more by the degree of *Kudoa* infection of the whiting muscle than by the temperature and length of time of storage of the fish after catch.

Superchilled Seawater

Whiting held in superchilled seawater (SCSW) for 1-2 days were examined for texture. Whole fish frozen after 1-2 days in 28.5°F seawater served as a reference point for texture of whiting as landed ashore and before plant processing. Sensory ratings for whiting samples (Table 6), were evaluated according to the sampling sequence of Figure 1. Differences in texture for whiting held in SCSW for 1 and 2 days are shown both for frozen controls and for whiting after freezing, thawing, and holding for 1 and 2 days at 34°F prior to refreezing for cooking.

The control samples representing fish held for 1 day in the SCSW were found to have normal textures when slow or fast cooked from the frozen state. When they were thawed and held for 1 day at 34°F, 12 percent had mushy textures when baked; but when fast cooked, all samples had normal textures. When thawed and held for 2 days and slow cooked, 26

percent had unacceptable textures. Again, all samples had acceptable textures when fast cooked. These results suggest that the proteolytic activity of the cysts in the 1-day superchilled fish was fairly localized despite 2-day chilled storage treatment after being thawed.

When baked from the frozen state, 6 percent of the control samples prepared from whiting held 2 days in SCSW had a mushy texture. All these samples were found to have normal textures when deep fried. When thawed and held refrigerated for 1 day, refrozen, and then slow cooked, 12 percent of the samples examined had a soft to mushy texture. Only 2 percent had unacceptable textures when fast cooked. No texture defects were observed when the crisp breading was left on. A similar trend in texture analyses was observed in the whiting that were refrigerated for 2 days after thawing.

It is interesting to note that the texture of the whiting frozen in dry ice at sea (Table 5) and held for 1 and 2 days in superchilled seawater and frozen (Table 6) was normal—without any significant evidence of softness when fast cooked from the frozen state. Thus, it appears that the freshly landed whiting, after being rapidly chilled and held up to 2 days in the superchilled condition, does not undergo serious deterioration of texture. The fact that the fish that were held for 2 days in SCSW had normal textures may be highly significant. This suggests the possibility that rapid chilling followed by maintenance of temperature by superchilling may keep the proteolytic enzyme localized within the cyst during the holding period. If this supposition is correct, it might permit extended vessel trips of up to 4 days with little difficulty. Thus, it would give the catcher vessel and/or the processing plant extra time needed for the successful exploitation of this species.

Table 6.—Comparison of slow- and fast-cooked sensory texture[1] of fillets from Pacific whiting held in superchilled seawater for 1 to 2 days, frozen whole, sectioned[2], and stored at 34°F for 1-2 days and frozen.

		Average ratings in each texture category											
		Frozen control				Thawed: 1 day @ 34°F and refrozen				Thawed: 2 days @ 34°F and refrozen			
		Slow cooked		Fast cooked		Slow cooked		Fast cooked		Slow cooked		Fast cooked	
Vessel treatment	Texture scale	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1-day superchilled (28-29°F)	5 Normal*	41	82	49	98	29	58	38	76	23	46	37	74
	4 Normal-	7	14	1	2	11	22	11	22	7	14	12	24
	3 Soft	2	4	0	0	4	8	1	2	7	14	1	2
	2 Overly soft	0	0	0	0	3	6	0	0	6	12	0	0
	1 Mushy	0	0	0	0	3	6	0	0	7	14	0	0
2-day superchilled (28-29°F)	5 Normal*	36	74	49	100	34	69	37	76	28	57	36	74
	4 Normal-	8	16	0	0	7	14	9	18	7	14	8	16
	3 Soft	2	4	0	0	2	4	2	4	5	10	3	6
	2 Overly soft	0	0	0	0	4	8	1	2	3	6	2	4
	1 Mushy	3	6	0	0	2	4	0	0	6	12	0	0

[1]Average texture is indicated for each fish. Where over 25 percent of the fish sample had a 1 or 2 texture, the entire fish was rated 1 or 2. The texture of the fast-cooked, battered-and-breaded, deep-fried product was graded on the basis of the fish alone after removing the breading.
[2]Each whiting was cut into 3/4-inch slices from nape to tail and sequentially placed into six treatment groups as indicated on the table. The slow- and fast-cooked comparisons of texture represent adjacent slices from three to five sections from nape to tail for each fish.

Comparison of Cooked Textures of IQF Fillets and Fillet Blocks

To determine whether the marketing form influences the incidence of mushy or pasty texture in cooked whiting samples, a taste panel comparison was made of the texture of deep-fried IQF fillets and portions cut from whiting fillet blocks. Fish that were caught and machine filleted aboard the trawler *Willapa Bay* in June 1978 and iced for 1½ days before freezing into IQF fillets or fillet blocks were used in this experiment. Of 324 deep-fried IQF fillet portions tested, 13 portions (4 percent) had borderline texture and 7 portions (2.2 percent) had unacceptable mushy or pasty texture. The amount of the fillet portion that had this unacceptable mushy or pasty texture varied from relatively small areas to almost the entire portion.

In evaluating the texture of portions cut from five 14-pound frozen fillet blocks (20″ × 11½″ × 1¾″), each block was cut lengthwise into three slabs about 20″ long, 3⅜″ wide, and 1¾″ thick. Each slab was then cut into portions ⅜″ thick, 1¾″ wide, and 3⅜″ long. About 135 portions were cut from each 14-pound fillet block.

Every fifth protion was "slow cooked" by baking for 25 minutes in an oven at 350°F to determine the distribution within the fillet block of any mushy or pasty fillets. When a portion was judged by the panel as unacceptable (mushy or pasty) in texture when slow cooked, the four portions that were adjacent to the portion judged mushy were battered-and-breaded, deep fried, and judged for texture.

Of the five fillet blocks examined, one block has all portions with acceptable texture; three blocks had several portions that were mushy or pasty when baked but were of acceptable texture when deep fried; and one block had two portions cut from two out of three slabs that had small areas of mushy/pasty texture.

The results of this experiment demonstrate that the relatively small number of fillets that become mushy when cooked rapidly would have less of a negative impact on consumer acceptance if they were used as part of a

fillet block rather than as an IQF fillet because of the dilution effect in the portions cut from fillet blocks.

Texture Improvement

Whiting fillets of otherwise good quality tend to show a significant amount of drip when held under refrigerated storage, frozen and thawed, or cooked. For whiting to be used as fresh fillets or frozen blocks, it would be desirable to reduce the drip and firm the muscle texture. Treatments with polyphosphates and salt are used in other meat products for such purposes. Based on the experiments in our laboratory with treatment of other fish, we implemented studies to determine the effectiveness of a combined 7.5 percent sodium tripolyphosphate plus 2 percent sodium chloride dip treatment on chilled whiting fillets.

Separate groups of whiting fillets were selected at random from a single lot, treated as above, and stored with untreated controls for 11 days at 33° and 36°F. The treated fillets had no free drip, whereas the control group had 2.3 percent drip. On being cooked, the treated samples continued to show lower drip (3 percent vs. 5 percent). Evaluation of texture by means of the hydraulic shear instrument (Dassow et al., 1962) showed that the treated samples had a firmer texture with 1.7 times greater shear resistance than the untreated fillets.

Frozen Storage Characteristics

Pacific whiting is very susceptible to the development of oxidative rancidity during frozen storage. The dark, fatty layer next to the skin and adjacent to the lateral line is particularly vulnerable to rapid oxidation. Of course, the degree of protection provided by packaging materials as well as the temperature of storage has a major impact on the degree of oxidative change. In addition, antioxidants can be used to provide significant protection against oxidation.

The dark, fatty layer along the lateral line can be partially removed by using a processing technique called "saberizing" or "deep-skinning." During machine skinning, the blade of the skinning machine is adjusted to an opening that removes a thin layer of flesh along with the skin. This removes all but the thickest portion of dark flesh. The major disadvantages to this practice are the need to closely control the skinning operation and the loss of usable flesh compared with normal skinning. However, the procedure can and does influence the quality of the frozen fillet, fillet blocks, and portions held in frozen storage.

Table 7.—Development of rancidity in Pacific whiting portions stored at 0° and 20°F with and without glaze.

Storage conditions		Sensory score (rancidity[1] of whiting portions after storage for (weeks):											
		0	2	3	4	5	6	10	13	18	24	30	36
0°F	Unglazed	8.3	4.3	5.3	4.0	4.6	4.0	3.5	2.7	3.3	2.0		
	Glazed	8.3	7.3	5.6	8.0	7.0	6.0	6.7	4.7	4.3	5.7	3.0	
−20°F	Unglazed	8.3	6.0	7.7	7.7	6.6	8.7	7.7	6.0	5.7	4.7	5.0	3.5
	Glazed	8.3	8.3	8.0	6.0	6.3	6.6	8.0	6.7	5.7	6.3	4.3	4.0

[1]A score of 10 indicates no detectable rancidity; scores from 9 to 6 indicate increasing rancidity with an overall acceptable rating; italicized scores of 5 or less indicate rancidity with an overall unacceptable rating.

Frozen Fillet Blocks

During storage tests conducted at 0°F on frozen blocks made from whiting fillets, taste panel evaluations of the texture and flavor of the lean flesh showed little adverse change, but that early oxidative rancidity was apparent in the fatty surface flesh (Table 7). Unglazed whiting portions cut from the blocks and stored at 0°F became rancid within 2 weeks. However, ice-glazed portions stored at the same temperature were acceptable for at least 10 weeks. If glazed and stored at −20°F, the portions were acceptable for up to 24 weeks. With suitable antioxidants and packaging to provide protection from oxidation, the storage is extended significantly.

The strong oxidative rancidity that developed in unglazed whiting portions stored for only 2 weeks at 0°F demonstrated that the lipids in the surface fatty layer of whiting are highly labile. Nevertheless, the limited tests made show that blocks of frozen whiting can be packaged and stored successfully at lower temperatures. Inasmuch as glazing is normally not feasible in blocks (most blocks are cut into portions and breaded), the use of approved antioxidants and packaging films with low oxygen-transmission characteristics should be encouraged.

Recent studies by the NWAFC Utilization Research Division have demonstrated that whiting blocks can be successfully held in frozen storage if the fillets are treated with a combination of erythorbate and phosphate at the time the blocks are prepared. The solution used to treat the fish contained 2 percent sodium chloride, 2 percent sodium erythorbate, 2 percent sodium hexametaphosphate, and 4 percent sodium tripolyphosphate. The treatment is effective in retarding rancidity for at least a 6-month period when the blocks are held at 0°F and longer at −20°F.

Results of comparative analysis for chemical changes occurring in the whiting fillets blocks during 6 months of storage at 0°F (Table 8) show that the untreated (control) blocks had 2-3 times as much malonaldehyde (as measured by the thiobarbituric (TBA) test for oxidative rancidity) as the block samples treated with sodium erythorbate. A TBA value of 0.36-0.40 micromoles of malonaldehyde/100 g is considered indicative of a moderate to strong degree of organoleptic rancidity in frozen whiting. Saberizing fish in this study did not appear to significantly protect the fillets from the oxidation process. Sensory evaluations made on the

Table 8.—Thiobarbituric acid, free thaw drip, express drip, cook drip, and shear texture measurements of Pacific whiting fillet blocks treated with chemical dips or saberized[1] after 6 months of 0°F storage.

Description of lots	TBA: Average of 2 (M/100 g)	Free thaw drip: Average of 3 (%)	Express drip: Average of 2 (ml/20 g)	Cook drip: Average of 3 (%)
Control: Whole fillets	0.24	4.4	9.5	18.0
Control: Chopped fillets	0.35	4.8	8.4	21.8
Saberized fillets	0.22	4.4	8.8	24.4
Erythorbate-phosphate dipped	0.12	3.1	7.6	12.9

[1]Saberized: Deep-skinned to remove most of the dark flesh from the fillet.

Table 9.—Results of sensory evaluations of steamed and deep-fried Pacific whiting fillet blocks treated with chemical dips or saberized[1] after 6 months in 0°F storage.

Sample treatment	Appearance	Odor[2]	Flavor[2]	Texture[2]	Desirability[2]	Rancidity[3]
Steamed						
Control: Whole fillets	6.6	5.8	5.5	5.9	5.2	1.9
Control: Chopped fillets	6.6	6.3	5.7	6.1	5.3	2.0
Saberized fillets	6.8	6.3	5.2	5.6	4.9	1.8
Erythorbate-phosphate dipped	6.3	6.4	6.3	6.6	6.1	1.2
Deep Fried						
Control: Whole fillets	7.3	7.1	6.4	6.2	5.7	2.1
Control: Chopped fillets	7.0	6.9	6.1	6.1	5.8	2.2
Saberized fillets	7.4	7.4	7.2	6.5	6.8	1.0
Erythorbate-phosphate dipped	6.7	7.1	7.3	6.8	6.8	1.0

[1]Saberized: Deep-skinned to remove most of the dark flesh from the fillet.
[2]Rated on the 9-point hedonic scale: 9, Like extremely; 8, like very much; 7, like moderately; 6, like slightly; 5, neither like nor dislike; 4, dislike slightly; 3, dislike moderately; 2, dislike very much; and 1, dislike extremely.
[3]Rated on a scale of 1 to 5: 1 = none, 2 = trace, 3 = slightly, 4 = moderate, and 5 = strong.

whiting block samples generally support the results of the chemical analysis for rancidity.

Taste panel scores given in Table 9 show that, irrespective of the method of cooking (steamed or deep fried), the erythorbate-treated whiting fillet blocks were found to be essentially free of rancid flavors. The apparent differences in sensory attributes evaluated between the steamed and deep-fried samples are attributed to the masking effect of breading on flavor and texture characteristics. Treatment with phosphates resulted in lower free, express, and cooked drip loss in the erythorbate-treated samples than in the control samples. Minimizing the formation of drip in whiting helps to stabilize the adhesive properties of the breading material during cooking.

Frozen H&G Whiting

Frozen headed and gutted (H&G) whiting is also subject to oxidative rancidity during storage. Since the headed and gutted fish is normally frozen with the skin on, there is some protection from the skin layer plus the thin layer of ice formed on the skin during freezing. Once the ice layer is lost and oxygen is available to penetrate the skin, rancidity will develop. The rate of development depends upon time, temperature, the degree that temperature fluctuates during storage, and the form of packaging.

On-shore Processing Study

Research conducted aboard fishing vessels during the period 1976-80 showed that Pacific whiting could be successfully held at sea for periods of at least 2 days. These results prompted a pilot scale shore-side processing study completed in 1980. The purpose of this study was to determine the feasibility of commercially processing Pacific whiting into fillet blocks. The test included the use of automated processing when possible. Two major questions were to be answered by the study. These were: 1) Would the quality of the blocks be acceptable? 2) Would the labor and other processing costs be reasonable?

Plant Layout

The process study was conducted at a fish plant located at Astoria, Oreg. Processing space was leased for the study, and workers were paid directly by the project. Equipment was leased when required and included an 8″ Temco pneumatic unloader[2], a Baader 160 heading and gutting machine, a Baader 188 filleting machine, and a Trio skinning machine. The schematic diagram in Figure 4 shows the flow of product through the processing line. Figure 5 shows the actual layout of the plant.

Fishing

The fish required for the study were caught by the chartered commercial fishing vessel *Kupreanof*. Six fishing trips were made from the port of Astoria during August and September. Because the fish were so widely dispersed, fishing was confined to standard roller gear. Each trip lasted from 1 to 2 days with an average catch of 21,522 pounds per trip. The fish were held aboard the vessel in superchilled seawater as discussed earlier.

Results

Unloading the Vessel

Fish from the first two trips were unloaded by hand because the pneumatic pump was not in place. The unloading was done by plant employees stationed in the vessel well and on the dock. Shrimp forks with rounded tines were used to scoop fish into a metal bucket which was then dumped into plastic totes containing slush ice (a mixture of water and flake ice).

Beginning with the third trip, the

[2]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

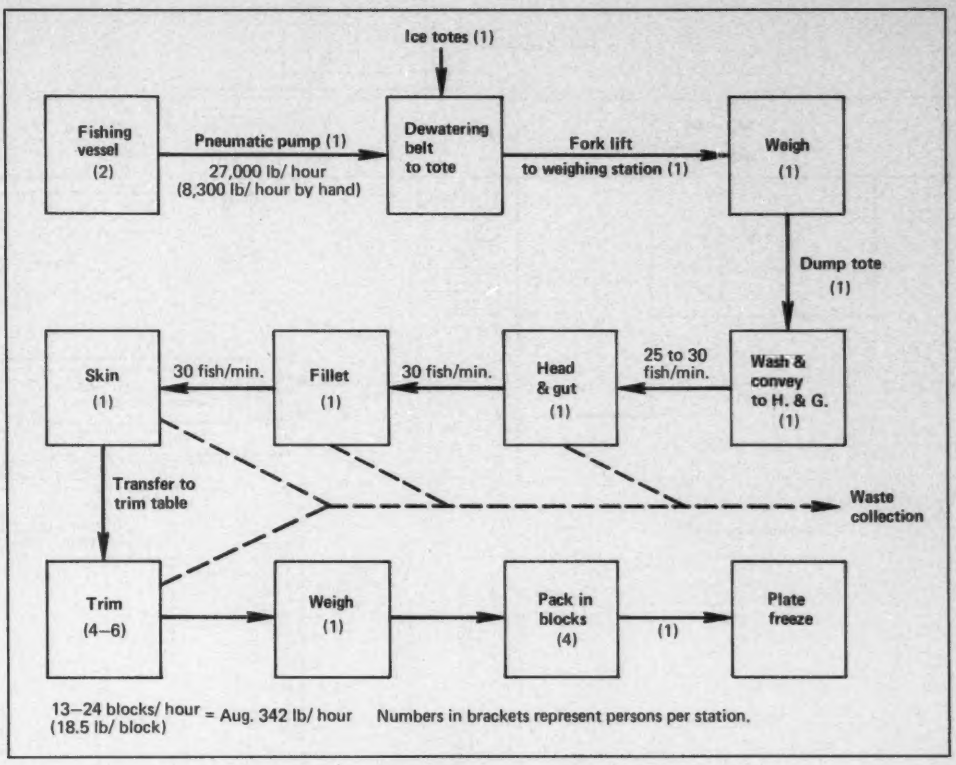

Figure 4.—Fillet block product flow diagram.

fish were unloaded by pump. the pump greatly facilitated unloading and increased the rate from the 8,300 pounds per hour achieved by hand to 27,000 pounds per hour. Damage to the fish was minimal (estimated at less than 1 percent). The fish discharged from the pump were passed over a dewatering belt, then into tared totes containing slush ice. Each tote was weighed and top iced.

Processing

Actual processing was begun by emptying totes of preweighed whiting into a wash tank that was designed with a chain-link conveyor and spray washer that transferred the fish into the processing room. Water used in the spray washing operation was prechilled to about 33°F to help maintain the fish at a low temperature during processing. Once in the processing room, the fish were hand loaded into the Baader 160 heading and gutting machine. Fish from the header and gutter were conveyed by gravity to the operator of the filleting machine. The heading and gutting operation easily maintained sufficient speed to keep up with the filleting machine. The header and gutter was a source of loss in yeild, the amount of which depended on the size and condition of the fish and the ability of the operator. Small fish frequently fell from the station to the waste chute. Inattention by the operator also resulted in unnecessary loss of fish. Although the machine is capacity-rated at 45 fish per minute, it was never operated at that level because the operator could not maintain the pace for any length of time. Actual sustained feed rates ranged between 25 and 30 fish per minute.

Filleting

The Baader 188 was used to fillet all of the product used in block production in the study. Normally the Baader 188 does not remove the pinbones from the fish. A slight modification of the cutting blade angle was made which resulted in pinbone removal. Of course, the yield was adversely affected. Boned-out, trimmed fillet yields ranged from 17.3 to 20.5 percent. The filleting machine was operated at about 30 fish per minute.

The average size of the fish during most of the study was 2.0 pounds and ranged between 1.9 and 2.1 pounds. At the rate of 30 fish per minute, the fillet machine would theoretically pro-

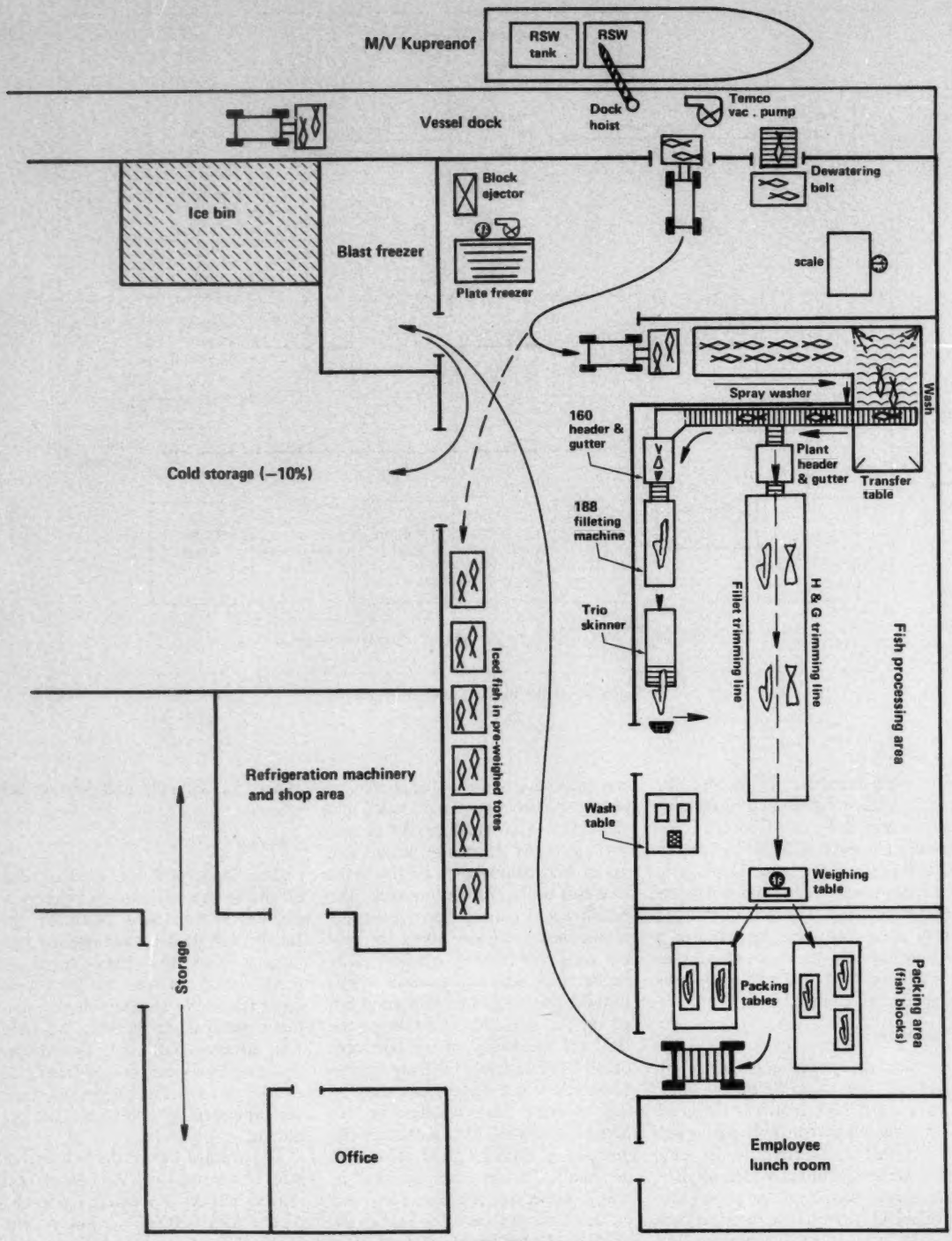

Figure 5.—Pacific whiting processing line layout.

duce 720 pounds of fillets per hour, assuming an average of 0.4 pounds per fish. In actual practice, downtime and employee breaks would reduce the theoretical yield by 25 to 50 percent. Thus, a sustained fillet production estimate of 360-540 pounds per hour is more realistic.

Skinning

The skinning operation using the Trio skinning machine easily kept pace with fillets delivered by the filleting machine. One operator was required to properly feed the skinning machine. The cutting blade was adjusted to remove as much dark flesh as possible in one pass without significant removal of light flesh. Although resulting in lower yields, deep skinning avoided the rancidity problem observed in earlier research with frozen whiting where the fatty layer was not removed.

Trimming and Weighing

Despite the care and precautions used in filleting and skinning, it was essential to inspect each fillet for remaining skin and bone and trim when necessary. Fillets with visually apparent infection of *Kudoa* parasite were removed.

Block Makeup

The block preparation step was the bottleneck of the operation. Some of the problem can be attributed to lack of experience as the workers were not familiar with the manufacture of fillet blocks which required special handling procedures. Some employees required up to 15 minutes to complete an 18.5-pound block because they were required to carefully place individual fillets into cartons. Since each block averaged 90 fillets, it is understandable that labor input was intensive.

Near the very end of the study, it was decided to speed up the block-making operation by producing a modified block product. This block was made by diagonally slicing fillets into small pieces (about 2 in wide) and then randomly filling the block cartons with the correct weight of the chopped product. This approach to the production of blocks required significantly less time to make a block of the same general quality as the fillet block made by the old method. An 18.5-pound block could be made in about 1 minute.

Freezing and Storage

The completed fillet blocks in their frames were frozen in a pressure plate (average of 260 psi) freezer at −35°F. The frozen blocks were removed from the frames by a pneumatic block ejector and stored in plastic totes in the plant cold storage at −10°F until they could be packed in master cartons.

Quality Evaluation

Owing to uncertain marketing conditions for whiting blocks at the time this study was made, the block products made during this study were not evaluated commercially. The blocks were tested, however, by the NWAFC Utilization Research Division. Using U.S. Department of Commerce standards for frozen fish blocks, whiting blocks, stored for 3 months at −15°F, were rated as "U.S. Grade A" in all categories except for cooked texture. Deductions for such factors as color, blemishes (skin, blood spot, fin, etc.) and dehydration were determined to be minor. However, the persistent problem of enzymic breakdown was seen as pockets of soft or mushy flesh in the thawed blocks and in the slow-cooked (baked at 350°F) samples, and the blocks were hence rated as "U.S. Grade B" or substandard depending on the degree and extent of the texture problem. This particular problem was also observed in a Pacific whiting demonstration project aboard the offshore factory trawler M/V *Blue Ocean* (1980). All of the blocks tested had normal textures when fast-cooked.

Headed and Gutted

In addition to the leased processing equipment, a heading and gutting machine owned by the plant was used occasionally. The machine, manufactured by Bel-Elm Industries of South Bend, Wash., used a circular saw blade for removing the heads from fish and a vacuum apparatus to aspirate viscera from the carcass. The machine processed about 120 fish per minute or as fast as the operator could hand feed it. This system was employed when a glut of whiting occurred that could not efficiently be handled by the filleting operation or when mechanical problems were encountered on the filleting line. At these times, fish would be diverted through the plant's heading and gutting machinery to compensate for the backup of fish.

Headed and gutted fish were washed and trimmed and packed into 20-pound cartons. The cartons of fish were then sent to the sharp freezer where they were frozen.

The quality of the H&G product was not evaluated. However, experience from previous H&G research would indicate that some of the H&G product would undoubtedly have an unacceptably soft texture, but otherwise by of good quality. The results of processing studies conducted aboard the M/V *Blue Ocean* (1980) did not indicate a problem with the texture of H&G ocean-caught whiting introduced into the consumer market.

Production Analysis

The study was planned to be completed during the summer season when whiting was readily available along the Oregon-Washington coast. However, funding was delayed and the project was not begun until late August. Unfortunately, the whiting were not available in large concentrations during the period of operation in September. This resulted in a rather short operation in which processing was done only 1 or 2 days per week. With any new program of this nature, there is a learning curve. Thus, considering poor fishing conditions which limited processing time, persons managing the project had insufficient time to adequately train plant personnel in the operation of equipment or with processing techniques necessary to produce quality fillet blocks. It was not until nearly the end of the project

that a reasonably smooth operation was obtained.

In the beginning of this section, it was stated that it was not the intent of this project to do a complete economic and marketing analysis but rather to assess the basic costs of producing a quality, machine-processed whiting block. The data presented below therefore reflect only those direct costs dealing with labor (time) and production but not packaging material, miscellaneous supplies, energy, maintenance, or repairs. Indirect costs such as insurance, depreciation, administration, etc. were also not considered in this study.

The data in Table 10 show the breakdown in man-hours of labor to produce the H&G and fillet-block products in this study. Labor man-hours shown under "Fillet Blocks" for foremen and maintenance include the time required to modify and test the Baader 188 filleting machine to remove pinbones. Although the filleting machine produced a fillet with good appearance, it required considerable maintenance by an experienced operator/plant engineer to keep it operating normally during the project. The man hours under "Fillet Blocks" for machine operators include processing time on the Trio fish skinner. As expected, those operations requiring the most labor in this project involved the filleting/packaging phase of block production.

The relatively low block production rate, i.e., 9.3 pounds/man-hour (Table 10) is attributed in part to the inexperience of the machine operators, the capacity and design of the Baader heading and gutting machines, and to the labor intensive trimming and packaging operations. By comparison, block production rates in the Blue Ocean project (1980) were almost double the production in this study. This was achieved by using Baader's latest and fastest filleting machine (Model 190) which, when properly adjusted, produced a fillet faster and required less trimming and handling than what was experienced in this project.

Costs in time of production are shown in Table 11. As explained, these figures only reflect those costs attributable to labor. The general market price for whiting fillet blocks at the time of this project was about $0.80/pound, well under the costs observed here. Based on these actual labor costs, the figures given in Table 12 were prepared to show projected costs for the production of fillet and H&G fish blocks at various hourly pay rates. Table 13 shows the comparative costs of the fish for various fillet yields as they were obtained from actual production and from a controlled test.

Markets

Prior to 1979, Pacific whiting was marketed in the United States as Pacific hake. The rationale followed by the U.S. Food and Drug Administration for changing the name in 1979 was to avoid whatever negative reputation that is associated with "hake" and to use a name nearer to one that is shared by other fishes of the genus *Merluccius* (Anonymous, 1979).

Pacific whiting has been marketed with limited success as fresh and frozen fillets, fillet blocks, and in the headed and gutted form. The most notable success has been the H&G product utilizing the Puget Sound stock of fish. The average size of the Puget Sound whiting and the Canadian whiting taken from the Strait of Georgia is small enough to make them ideal for the H&G market. These areas provide an excellent winter and spring fishery for a limited number of vessels. The fish are available in good concentrations and can be taken readily in water protected from all but the most severe storms. Since 1979, in excess of 20,000 metric tons (t) of Puget Sound whiting have been landed. However, it was not until the 1980-81 fishing season that these whiting were designated for food fish when 21 percent of the landings were used for human consumption. Until then, the whiting were mainly harvested for industrial use. Since the 1980-81 season, essentially all of the landings have been processed as food fish. In 1982-83, 90 percent of the landings, (6,551 t) were processed as food fish. The waste is converted by local rendering companies as a by-product of this activity. It is estimated that

Table 10.—Pacific whiting production labor in man hours.

Item	H&G product	Fillet blocks	Total
Unload	55	75	130
Foremen and maintenance	100	310	410
Machine operators	101	304	405
Butcher/fillet	69	332	401
Pack/weigh/cleanup	151	454	605
Freeze/warehouse	57	79	136
	533	1,554	2,087
Production (lb.)	23,940	14,465[1]	
Production (lb./man-hour)	44.9	9.3	

[1]Total includes 1,960 pounds of fillets frozen individually.

Table 11.—Actual labor costs per pound production.

Item	Headed and gutted	Blocks
Production (lb.)	23,940	14,465
Payroll/man-hour = $9.08		
Man hours	533	1,554
Average production/man-hour	44.9	9.3
Cost per pound	$\frac{9.08}{44.9} = \$0.202$	$\frac{9.08}{9.3} = \$0.976$

Table 12.—Projected production costs at various labor costs.[1]

Item	Production costs at $8.00/hour	$8.00/hour	$10.00/hour
H&G/pound	$0.134	$0.178	$0.222
Blocks/pound	$0.645	$0.860	$1.08

[1]Based on average production rates achieved during this study.

Table 13.—Fish cost based on various yields.

Yield	Fish cost $0.06/lb.	$0.07/lb.	$0.08/lb.	$0.10/lb.
17% yield[1]	$0.353	$0.412	$0.471	$0.588
20% yield	$0.300	$0.350	$0.400	$0.500
23% yield[2]	$0.261	$0.304	$0.348	$0.435

[1]Actual yield obtained during this study.
[2]Yield obtained during controlled test using 100 fish.

Puget Sound can produce about 10 million pounds of whiting per year for commercial use[3].

Although the "inside" whiting is infected with the *Kudoa* parasite, the tissue is not as adversely affected as that of the "outside" or ocean whiting. Tsuyuki et al. (1982) reported significant differences in the texture between the inside and outside whiting that can be attributed to the difference in enzyme activity associated with the species of *Kudoa* that infects the two groups.

Landings of Pacific whiting were almost nil until the middle 1960's when several events occurred that stirred interest in the species. Exploratory fishing along the coasts of California, Oregon, and Washington demonstrated that a substantial stock of the species was available and that huge catches could be made by the use of midwater trawls. In 1965, a fish reduction plant was built at Aberdeen, Wash., especially to process Pacific whiting. Unfortunately, the price of fish meal on the world market dropped during the time the plant was in operation. Thus, the price of fish for reduction was affected and fishermen were reluctant to deliver whiting to the fishmeal plant at the price offered. During the same period the Bureau of Commercial Fisheries (now the NMFS) was developing technology to produce fish protein concentrate (FPC) from lean, white-fleshed fish. Aberdeen, Wash., was selected as the site for a demonstration pilot-scale plant to produce FPC. The FPC plant operated during 1971 and 1972, but was closed when funds to operate were no longer available. Private attempts to produce FPC from whiting also failed when markets did not develop as predicted. Even countries with shortages of protein foods did not accept FPC as a nutritional supplement.

[3]Mark G. Pedersen, Chief, Groundfish Management, Washington Department of Fisheries, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115, and Dale Ward, Research Analyst, Washington Department of Fisheries, 115 General Administration Building, Olympia, WA 98504. Unpubl. data.

Attempts to market Pacific whiting in the fillet block form have also not been completely successful due to a combination of factors. First, potential users have rejected the product on the basis of the texture problem. Second, the cost of production of domestically produced blocks has made it difficult to compete with imported whiting blocks. Third, there has not been a major effort to sell whiting blocks produced on the Pacific Coast. The first two factors are good explanations for the third.

Marketing Pacific whiting will continue to be a problem as long as the limitations dictated by the presence of the *Kudoa* parasite are ignored. The texture problem can be overcome by using a specific technique of cooking such as deep frying portions. Slow cooking methods simply are not acceptable unless the fish is free of the parasite.

Present Situation

The brightest spot in the current market situation for Pacific whiting is the frozen H&G product from the Puget Sound area. Several companies are engaged in H&G operations. The current price of $0.32/pound is competitive with foreign imports. The operations are providing two important benefits. One, fishermen and processors are working; and two, good quality fish is going onto the market at reasonable prices.

Small quantities of Pacific whiting are being reduced to fish meal in the Puget Sound area. Of course, the quantity of fish available for reduction is adversely affected by the demand for fish to be processed into the H&G form.

Northern California plants continue to produce H&G products and fillets. In addition, at least one company has the capability of producing fillet blocks.

Joint ventures in which American fishing vessels catch whiting and transfer the net codends directly to foreign factory ships are continuing. This has provided a source of income to a number of vessels that might not have markets otherwise.

Interest in processing ocean whiting remains high. The major impediments to successful development, however, remain the soft texture, production costs, and market demand. Potential for developing new products from whiting will be discussed in the following section.

Future Markets

As mentioned, the predisposition of ocean-caught Pacific whiting to have soft-textured flesh places limitations on the method of cooking the fish. Because of these limitations, the product form and the markets that can accommodate this fish should be considered. From our experience, fillet blocks would appear to offer the most viable product form for marketing. If Pacific whiting blocks are properly cut into protions, battered and breaded, then cooked by frying in deep fat, the product can be excellent. Fillets can also be portioned and cut to reduce thickness to about ⅜ inch and handled in the same way with good results. The requirement to use only deep frying as the cooking method is a major problem and may make marketing very difficult.

Other possibilities for marketing Pacific whiting are dependent on overcoming the texture problem. One potential is to market fillets that are cooked in the processing plant. This would enable the processor to cull out the fillets that become overly soft during cooking. The cooked product could be prepared in TV-type dinners or as frozen entrees combined with sauces. The institutional market should also be explored as a potential for these types of products.

Another approach to marketing is in the fabricated food area. Minced whiting flesh should be evaluated for use as the raw material to prepare a wide variety of products such as imitation shrimp, crab legs, scallops, and other products that use cooked, minced flesh as the basic ingredient. The possibility is currently being researched by the National Marine Fisheries Service and the West Coast Fisheries Development Foundation.

Expansion of the ocean fishery in

any form of traditional products would be dependent on either developing a way of avoiding the highly parasitized fish or a way of detecting and removing during processing those individuals with a high level of parasites. Chemical treatment to inactivate the enzyme responsible for altering the texture is another possibility. Recent research, previously discussed, has shown that several chemicals control enzyme activity when minced whiting flesh is treated.

Production of industrial products such as fish meal, fish silage, and protein hydrolyzates from Pacific whiting, although technically feasible, does not appear economically attractive at this time. However, this outlook could change if other markets develop so that waste from filleting or mincing operations could be used to prepare industrial products.

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Pacific Whiting, *Merluccius productus*, Stocks off the West Coast of Vancouver Island, Canada

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Introduction

Pacific whiting, *Merluccius productus*, in Canadian waters form two distinct populations. One population is found in the Strait of Georgia and the other, known as "offshore whiting" is found primarily off the west coast of Vancouver Island. The offshore population can be distinguished from the inshore or Strait of Georgia population by its larger size and otolith growth pattern (Beamish et al., 1982; McFarlane and Beamish, 1985) and the presence of a parasite not found in Pacific whiting in the Strait of Georgia (Kabata and Whitaker, 1981).

The offshore Pacific whiting are mostly migratory fish that enter the Canadian zone in late spring and leave in the fall. There are some local spawning populations but they are small relative to the biomass of the migratory fish (G. A. McFarlane, unpubl. data).

This paper reviews the biology and fishery of the offshore Pacific whiting in the Canadian zone. This fishery is the most rapidly developing fishery on Canada's Pacific Coast, and it is timely to consider how the fishery in the Canadian zone should be developed in relation to the fishery off the United States. To do this, it is important to understand the timing of the migration in and out of the Canadian zone and the age, size, and sex composition of the fish.

Material used in this report was assembled from a number of sources, including Beamish (1981), and Beamish et al. (1982). Samples were collected from research vessels and foreign and domestic fishing vessels. Sampling methods varied, but in most cases subsamples of about 100 fish were collected without selection from the catch and, if possible, these samples were combined to make a total sample of about 300 fish per time/area. Pacific whiting were measured for fork length, sex was determined, and in some cases the state of maturity was noted. Otoliths were collected in pairs, stored in a 50 percent glycerin solution, and processed according to the procedures of Beamish (1979) and Chilton and Beamish (1982). Catches were estimated by prorating product quantities to round weight using conversion factors (Table 1).[1]

Table 1.—Conversion rates.

Year	Nation	Primary product	Conversion factor (dressed to round)
1977	Poland	Skinless fillets	unknown
1978	Poland	Skinless fillets	3.071
	U.S.S.R.	Skinless fillets	3.571
1979	Poland	Skinless fillets	3.125
		Skin-on fillets	2.326
		Boneless fillets	3.704
		Head off gutted	1.786
		Meal	5.555
1982	Poland	Skinless fillets	3.125
		Skin-on fillets	N/A
		Boneless fillets	3.704
		Head off gutted	1.786
		Meal from round	5.555
		Meal from offal	5.555

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ABSTRACT—Concentrations of Pacific whiting, Merluccius productus, *have been found in the Canadian zone as early as February and as late as November. A review of the commercial fishery suggests that a whiting fishery could be sustained for 4-6 months annually. Length frequency analysis and egg and larval surveys indicate the presence of resident spawning stocks off the west coast of Vancouver Island.*

The population consisted of about 70 percent females. The mean size of males and females increased each year from 1977 to 1981 and decreased substantially in 1982 as a result of the strong influx of 5-year-olds into the fishery. Whiting ranged in age from 2 to 20 years; however, the majority were in the 5- to 12-year range.

Catches are dominated by strong year classes. During 1982, the 1970, 1973, and 1977 year classes were dominant and accounted for 77 percent of all fish sampled. The fishery off Canada is dependent on older, larger, primarily female fish. These fish should be harvested conservatively until more is known about their role in sustaining recruitment.

Timing of Migration in and out of the Canadian Zone

Commercial catches by the U.S.S.R. off Canada from 1967 to 1975 (Table 2) indicate that Pacific whiting have been in commercial concentrations as early as February and as late as December. In 1979, a series

[1]B. Leaman, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada V9R 5K6. Unpubl. data, Nov. 1982.

Table 2.—U.S.S.R. catches (t) of Pacific whiting in the PMFC and/or INPFC area—Charlotte and Vancouver—by month, 1967-76.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1967													[1]11,000
1968		423			14,455		25,825				614		[2]41,317
1969					266		61,741				2,922		[3]64,929
1970					19,119		6,372						25,491
1971					4,741	1,355	3,844	4,321	1,474	6,844	3,410	72	[2]26,061
1972					1,879	6,888	5,018	11,574	9,643	4,195	4,102		[2]43,299
1973							2,148	3,442	2,546	5,703			13,839
1974							—[4]	1,867	15,144				[2]17,011
1975								3,493					3,493
1976							280	3,638					3,918

[1]This is an instance where catches were estimated or inferred from broader groupings, from Ketchen (1977).
[2]Landings in 1968 and 1969 are higher than previously reported by Ketchen (1977) and in unpublished documents from the International North Pacific Fisheries Commission (INPFC). These landings include a percentage of whiting which were reported as "other fish" but identified as whiting.
[3]Majority of these catches from U.S. portion of INPFC Vancouver Area.
[4]Unreported, but probably some catch at this time.

Table 3.—Monthly (Mar.-Aug.) mean sea surface temperatures (°C) at Amphitrite Point, west coast of Vancouver I. (lat. 48°55'N, long. 125°32'W).

Year	March	April	May	June	July	August
1960	9.7	11.0	10.8	11.2	13.3	13.4
1961	9.0	9.5	11.2	11.8	14.1	13.7
1962	7.6	9.4	10.6	11.1	11.2	13.1
1963	8.6	10.1	11.9	11.3	13.5	14.2
1964	8.7	8.9	9.2	11.3	12.7	13.2
1965	8.2	8.7	9.9	11.1	11.7	12.9
1966	8.1	9.6	10.0	11.7	12.3	12.2
1967	7.9	9.1	10.1	11.9	12.7	13.2
1968	8.7	9.1	10.6	11.7	12.4	12.9
1969	7.9	9.3	11.4	12.8	12.3	12.9
1970	9.1	9.5	10.2	11.2	12.4	12.5
1971	7.0	8.6	9.8	11.8	12.8	13.6
1972	7.9	8.4	10.3	11.4	13.0	13.8
1973	8.5	9.4	10.4	11.6	12.4	12.8
1974	7.7	9.0	10.0	10.7	13.0	14.0
1975	7.6	8.8	10.4	10.8	12.0	12.6
1976	7.1	8.8	9.9	10.8	12.9	12.5
1977	8.6	9.7	10.7	11.9	11.9	14.4
1978	9.1	10.1	11.1	13.7	13.3	13.1
1979	8.1	9.3	11.5	11.6	13.6	14.0
1980	8.7	10.1	11.3	12.1	12.7	13.4
1981	9.7	10.0	11.4	12.5	13.4	13.8
1982	8.2	9.2	10.2	11.5	12.4	13.4

of cruises demonstrated that commercially exploitable quantities of Pacific whiting were not present in mid-May but were by mid-June. Fishable concentrations remained until November. During 1979, the Canadian and foreign fishery started on 6 August and continued until 1 October. During this period there was no indication that the size of the stocks had declined to levels that would not support a commercial fishery.

In 1980, 1981, and 1982 the fishery started on 6 August, 11 July, and 1 July respectively, and terminated on 15 October, 19 October, and 31 October respectively. In 1982, fishermen reported fishable stocks as early as April.

It appears that movement in and out of the Canadian zone is variable. Large quantities appear to be present from mid-June until October and fishable quantities appear to be present for a slightly longer period, enabling commercial fishing for a minimum of 4-5 months and a maximum of 5-6 months.

The factors that control recruitment of Pacific whiting into the Canadian zone are unknown, but it is possible that adults may utilize the deeper California undercurrent to migrate north and that the strength of this current affects the extent of northerly movement. Since 1976, total catches have steadily increased (Fig. 1). Ketchen (1977) reported that Soviet scientists believed that migration into the Canadian zone in 1971 and 1973 was reduced because of the particularly cold water during these years. A review of surface temperatures in Canadian waters (Table 3) indicates no correlation between catches (Table 2) and temperature. Fluctuations in catches are probably a consequence of Soviet fleet management.

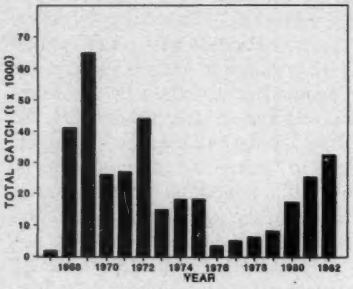

Figure 1.—Pacific whiting catch off the west coast of Canada and the State of Washington to lat. 47°30'N, 1967-76, and off the west coast of Canada, 1977-82.

Most Pacific whiting are concentrated southwest of Barkley Sound (Fig. 2). Some whiting are found in the Strait of Juan de Fuca, and their size and otolith growth pattern indicate that these whiting are from the offshore population (Beamish et al. 1982). Large Pacific whiting have been observed as far north as southern Hecate Strait (Fig. 3) (Thompson and Beamish, 1979). Pacific whiting in these northern waters are not abundant and it is unknown if they are part of the migratory "offshore" stock.

There are resident "offshore" stocks in Barkley Sound and Sydney Inlet as indicated by the samples of age 1 and age 2 fish (Fig. 4). These young whiting were first sampled in 1978, although fishermen had reported their presence previously. The 1983 sample shows the occurrence of the 1981 and 1982 year classes. Eggs and larvae have been collected from January to April off these areas,[2] clearly indicating the presence of resident spawning stocks.

Size and Sex Composition

The size and sex composition of fish has been monitored since 1977 (Fig. 5). The mean size of males over this 6-year period has ranged from 48.5 to 53.6 cm, and females from 50.7 to 56.9 cm. The mean size of both sexes increased each year from 1977 to 1981, then decreased substantially in 1982 (Fig. 6). This decrease

[2]J. C. Mason, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada V9R 5K6. Unpubl. data, Oct. 1982.

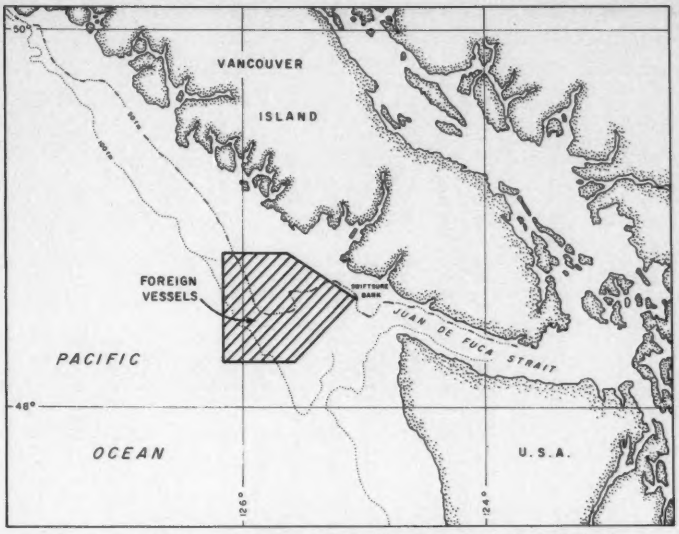

Figure 2.—Main concentration of Pacific whiting as reflected by the fishery.

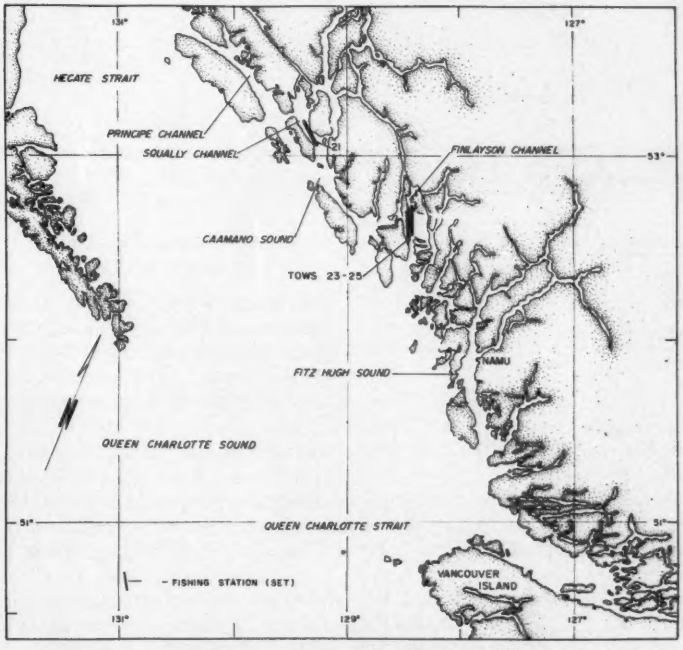

Figure 3.—Areas of capture of Pacific whiting in mainland inlets off Queen Charlotte Sound in southern Hecate Strait.

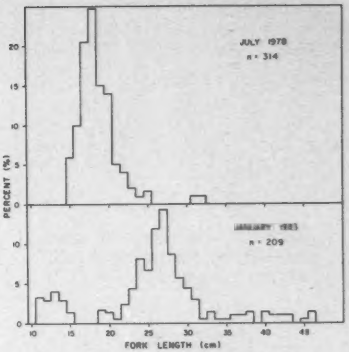

Figure 4.—Length frequency of Pacific whiting sampled off Sidney Inlet, 1978, and in Barkley Sound, 1983.

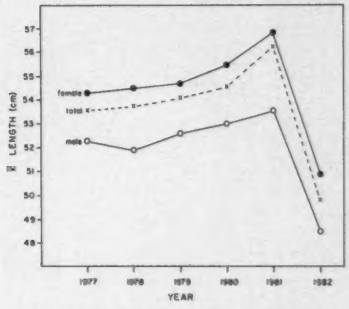

Figure 5.—Mean Length of Pacific whiting sampled from commercial catches 1977-82.

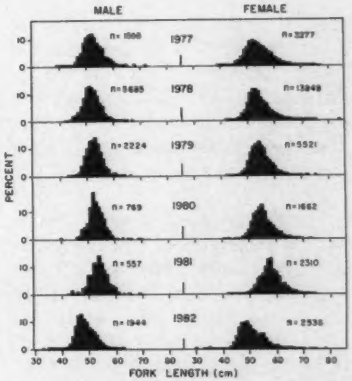

Figure 6.—Size distributions of male and female Pacific whiting sampled during the commercial fishery, 1977-82.

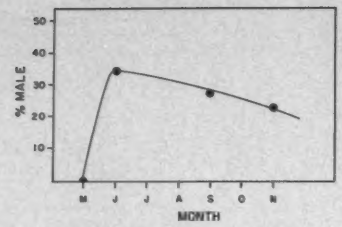

Figure 7.—Percentage of males in catch of Pacific whiting by month, averaged for 1979-82.

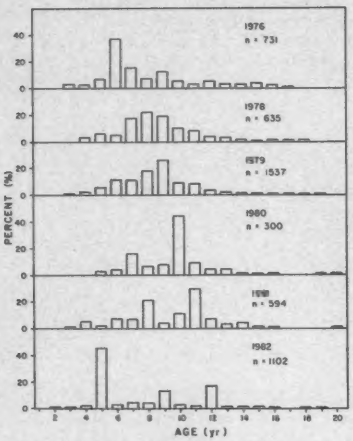

Figure 8.—Age composition of Pacific whiting catches, 1976-82.

Table 4.—Length frequency of Pacific whiting sampled throughout the period of residency in the Canadian zone, 1979.

Length (cm)	May			June			September			October			November			Total		
	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
42								1	1							1	1	
43		1	1		2	2	1	0	1							1	3	4
44		0	0		2	2	4	2	6							4	4	8
45		0	0		1	1	2	3	5	1	1	2	2		2	5	5	10
46		1	1		2	2	11	6	17	9	7	16	0		0	20	16	36
47		4	4	6	9	15	6	14	20	19	11	30	0		0	31	38	69
48		4	4	14	23	37	28	27	55	45	39	84	2	1	3	89	94	183
49		2	2	22	17	39	58	50	108	81	56	137	2	4	6	163	129	292
50		9	9	45	69	114	60	69	129	115	137	252	9	8	17	229	292	521
51		6	6	36	82	115	72	126	198	167	223	390	12	23	35	287	460	747
52		10	10	38	88	126	73	151	224	171	290	461	15	34	49	297	573	870
53		8	8	55	96	151	57	153	210	168	329	497	22	40	62	302	626	928
54		9	9	44	116	160	50	152	202	147	340	487	14	59	73	255	676	931
55		10	10	26	81	107	44	161	205	110	286	396	16	50	66	196	588	784
56		7	7	14	94	108	39	119	158	62	248	310	19	65	84	134	533	657
57		6	6	12	52	64	20	89	109	45	176	221	9	47	56	86	370	456
58		6	6	7	51	58	15	90	105	25	123	148	9	35	44	56	305	361
59		2	2	2	35	37	4	51	55	9	113	122	7	48	55	22	249	271
60		7	7	6	39	45	4	41	45	10	58	68	3	36	39	23	181	204
61		1	1	1	10	11	2	23	25	1	50	51	2	26	28	6	110	116
62		2	2	2	10	12	0	24	24	4	19	23	0	23	6		78	84
63		1	1	1	12	13	2	12	14	1	22	23	3	10	13	7	57	64
64		1	1	1	5	6		14	14	1	15	16	2	12	14	4	47	51
65		2	2		5	5		9	9		11	11	0	6	6	0	33	33
66		0	0		5	5		6	6		10	10	1	5	6	1	26	27
67		0	0		0	0		2	2		3	3		1	1		6	6
68		1	1		3	3		2	2		3	3		1	1		10	10
69					0	0		2	2		4	4					6	6
70					0	0		0	0		0	0					0	0
71					0	0		1	1		1	1					2	2
72					2	2					0	0					2	2
73											0	0					0	0
74											0	0					0	0
75											1	1					1	1
Total		100	100	332	911	1,243	552	1,400	1,952	1,191	2,576	3,767	149	534	683	2,224	5,521	7,745

Table 5.—Contribution (percent catch by number) of the strong 1970, 1973, and 1977 year classes to the Pacific whiting fishery in the Canadian zone.

Year class	Year					
	1976	1978	1979	1980	1981	1982
1970	36	22	26	44	29	17
1973	3	6	11	16	21	14
1977					5	45
Total	39	28	37	60	55	76

resulted from the strong influx of 5-year-olds (1977 year class) into the fishery. The entry of large numbers of this year class into the Canadian zone eliminated the dominance of the 1970 year class which was responsible for increase in mean size from 1977 to 1981.

The largest male measured 77 cm, but few males (about 1 percent) were larger than 60 cm. The largest female was 84 cm, but only 13 percent of the females were larger than 60 cm. The mean lengths of all males and all females sampled were 52 and 54.5 cm, respectively. These lengths can be converted to weights of 843 g, or 1.9 pounds, and 1,056 g, or 2.3 pounds, respectively (Shaw et al., In press).

Samples collected throughout the year indicated very little variation in size (Table 4).

Females dominate the catch. In all years since 1977 the percentage of females has been relatively constant, ranging from 60 to 82 percent. Males arrived later than females and left earlier (Fig. 7). The later arrival of males and their earlier departure are consistent with observations of spawning behavior in the Strait of Georgia, where males are first to arrive and last to leave the spawning area (Beamish et al., 1978; Cass et al., 1978; McFarlane et al., 1982).

Age Composition and Strong Year Classes

Offshore Pacific whiting in the Canadian zone are generally older than those in areas to the south. The range of ages is from 2 to 20 years, but most fish (87-97 percent) are in the 5- to 12-year range. The age at which most fish are recruited to the fishery is 5 or 6 years. Even when strong year classes are present, such as the 1977 year class, they are not present in the Canadian fishery until age 5 (Fig. 8). Once these strong year classes are recruited, they dominate catches for a number of years. Currently the 1970, 1973, and 1977 year classes are dominant, and in 1982 these three year classes accounted for 76 percent of all fish sampled (Table 5). Understand-

Table 6.—Relative year-class strength of Pacific whiting after correcting for total mortality.

Age	1975		1976		1979	
	n	*n* corrected for total mortality	*n*	*n* corrected for total mortality	*n*	*n* corrected for total mortality
5	1	2	70	108	85	131
6	5	12	535	1,266	262	620
7	8	29	137	499	156	568
8	13	73	103	577	303	1,697
9	13	112	164	1,413	263	2,267
10	13	172	67	888	74	981
11	8	163	30	612	60	1,224
12	13	408	58	1,183	31	973
13	26	1,255	32	1,004	12	579
14	30	2,228	28	2,080	10	743
15	22	2,514	60	6,856	10	1,143
16	6	1,055	33	5,802	2	352
17			11	2,975	4	1,082
18					1	416
19					2	1,280

Table 7.—Mean size (cm) and age (years) of Pacific whiting found off the west coast of Vancouver Island and off Washington and Oregon, 1976 (sample size in parentheses.)

Age	West Coast Vancouver Island			Washington and Oregon		
	Male	Female	Total	Male	Female	Total
3				43.0 (1)	45.9 (7)	45.5 (8)
4	50.0 (1)		50.0 (1)	44.0 (3)	46.6 (7)	45.8 (10)
5		52.0 (1)	52.0 (1)	48.8 (18)	49.3 (26)	49.1 (44)
6	52.5 (8)	53.0 (30)	53.3 (38)	48.4 (126)	49.2 (209)	48.9 (335)
7	50.0 (1)	53.5 (11)	53.2 (12)	48.1 (26)	49.6 (54)	49.1 (80)
8	53.0 (4)	58.2 (17)	57.2 (21)	50.0 (18)	52.1 (25)	51.2 (43)
9	61.0 (9)	59.3 (38)	59.6 (47)	51.7 (20)	53.1 (30)	52.5 (50)
10	55.5 (2)	58.6 (13)	58.1 (15)	52.4 (8)	53.4 (14)	53.0 (22)
11	62.5 (2)	60.0 (6)	60.6 (8)	51.6 (5)		51.6 (5)
12	63.0 (6)	63.3 (12)	63.2 (18)	50.8 (4)	54.4 (7)	53.1 (11)
13	62.0 (2)	64.4 (7)	63.9 (9)	53.0 (3)	55.8 (5)	54.8 (8)
14		59.0 (4)	59.0 (4)	51.0 (1)	51.6 (8)	51.5 (9)
15	55.3 (4)	62.4 (14)	60.8 (18)	50.4 (5)	55.0 (11)	53.6 (16)
16	53.0 (1)	58.8 (4)	57.6 (5)	51.5 (4)	54.3 (7)	53.3 (11)
17		67.3 (4)	67.3 (4)	51.7 (3)		51.7 (3)
Total	40	161	201	245	410	655

ably, the relative importance and the length of time in the fishery of these three year classes will vary according to their absolute abundance. It appears that strong year classes can continue to dominate for a number of years. For example, the 1970 year class has ranged from 17 to 44 percent of the catch since records were started in 1976. In 1982, it is still a prominant component as 12-year-olds representing 17 percent of the samples by numbers.

Strong year classes are a key parameter to understanding the biology of Pacific whiting populations. Dark et al. (1980) and Nelson and Dark (1985) reported that the 1977, 1973, and 1970 year classes were strong, and Stauffer and Smith (1977) reported indices of whiting larval abundance that suggest strong year classes occurred in the early 1970's, middle 1960's, and early 1960's.

A simple reconstruction of the age-frequency histograms for samples collected in 1975, 1976, and 1979 and corrected for a total annual mortality (A = 0.35; Beamish, 1981) indicates that there have been strong year classes in 1970, 1967, or 1968, 1964, and 1961 (Table 6). Presently there is a very strong 1980 year class[3] (G. McFarlane, unpubl. data) recruiting into the Canadian and U.S. fisheries. Thus, it is apparent that strong year classes have occurred in 1980, 1977, 1973, 1970, 1967 or 1968, 1964, and 1961. There appears to be a period of relatively successful years from 1960 to 1962; however, the small sample size of older fish and the possibility of aging errors make it difficult to assess relative year-class strength for these years. A reconstruction of cohort strength was also used for Pacific whiting by Bailey (1981) and appears to be an acceptable approximation of relative year-class strength. The development of strong year classes has been related to the presence of strong onshore currents (Ekman transport) during the spawning period (Bailey, 1981). However, the presence of an apparent 3-year cycle may also indicate a biological relationship.

Strong year classes do not persist as a dominant feature as long in the U.S. fishery. A commercial sample collected off California, Oregon, and southern Washington by U.S. scientists contained no major mode representing the 1970 year class after 1978 (Nelson and Dark, 1985). Thus by the time the fishery off the United States is usually underway, many of the largest and oldest fish have aggregated in the waters off Canada and northern Washington State.

A comparison of the mean size of similar age fish sampled in 1976 off Canada, Oregon, and Washington showed that not only do more of the larger fish occur in the Canadian zone, but individuals of any particular year class that move into Canadian waters are the larger fish of that year class (Table 7). The differences in the mean size of similar aged males and females from the two zones were highly significant (t-test, $p<0.01$, only sample sizes larger than 10 tested). These differences in size clearly demonstrate that large individuals undergo more extensive migrations and that larger individuals of each year class (after age 4 or 5) and large individuals in the population tend to migrate into the Canadian zone.

The mean size of males and females from the 1970 year class increased about 1 cm each year since 1976 (Fig. 9). Sampling problems and selective mortality rates can influence the estimate of annual growth. However, it is apparent that growth in length of older fish is minimal and that females probably are directing energy into reproduction and reserves for migration rather than for length increases.

The method of employing sections of otoliths or broken and burnt otoliths for aging Pacific whiting has not been validated. However, the identification of the prominence of the 1970 year class in successive age-frequency histograms up to the age of

[3]T. Dark, Northwest and Alaska Fisheries Center, NMFS, NOAA, 7600 Sand Point Way N.E., Seattle, WA 98115. Pers. commun., Nov. 1982.

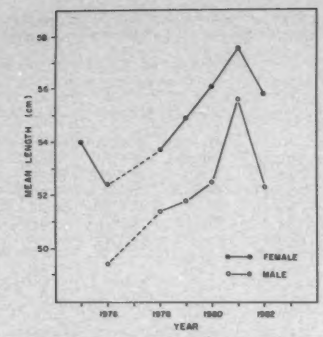

Figure 9.—Mean size of male and female Pacific whiting from the 1970 year class, 1976-80.

12 in 1982 (Fig. 8) indicates that the zone identified as an annulus does form once a year and the method is valid at least up to age 12.

Commercial Fishery

Since 1968, the largest catches in the groundfish fishery on Canada's west coast have been Pacific whiting. Total reported catches have ranged from 65,000 t in 1969 to 3,900 t in 1976. Prior to 1975 the U.S.S.R. caught the major percentage of whiting in the Canadian zone (Fig. 1). Poland and Japan landed much smaller quantities. After 1977 and the declaration by Canada of an extended fishing zone, the commercial fishery was divided into domestic, joint venture, and foreign fisheries.

Total catches of whiting have increased steadily since 1977 (Table 8) to 32,207 metric tons (t) in 1982. Participating countries have included Japan, Poland, Greece, and the U.S.S.R. While there is still no domestic market for offshore whiting, landings by Canadian fishermen directly to foreign vessels have increased substantially to 19,613 t in 1982.

As shown, the strong year classes are recruited to the fishery off Canada at age 5 or 6. The age at recruitment probably depends on environmental conditions as well as year-class strength. The strong 1977 year class was recruited as 5-year-olds in 1982 and accounted for 45 percent of the catch (numbers). The 1970 and 1973 year classes were recruited primarily as 6-year-olds. Preliminary analysis of 1983 data indicates that the 1980 year class was present in the Canadian zone and accounted for 6.2 percent of the catch. The increased catches in 1972 and 1969 probably indicate the presence of strong year classes, but it is difficult without age composition data to determine the year classes responsible. It is probable that the high 1969 catch was composed of a large percentage of the strong 1961 year class. It is apparent that the fishery in the Canadian zone is dependent on strong year classes.

Table 8.—Total landings of Pacific whiting by foreign and domestic fisheries off Canada, 1978-82.

Year	Nation	Total landings (t) Foreign national[1]	Joint venture	Domestic	Total
1978	Poland	589	1,814		
	U.S.S.R.	700	0		
	Japan	3,364	0		
	Total	4,653	1,814		6,467
1979	Poland	4,263	3,102		
	U.S.S.R.	0	1,131		
	Japan	3,637	0		
	Total	7,900	4,233	302	12,435
1980	Poland	4,456	4,560		
	U.S.S.R.	78	4,300		
	Japan	817	0		
	Greece	0	3,355		
	Total	5,351	12,215	96	17,661
1981	Poland	3,189	4,779		
	U.S.S.R.	227	7,342		
	Japan	187	0		
	Greece	0	4,927		
	Total	3,603	17,048	4,440	25,091
1982	Poland	10,357	10,222		
	U.S.S.R.	0	9,391		
	Japan	2,237	0		
	Total	12,594	19,613	2	32,209

[1]Includes landings from the supplementary fishery. Catches reported in this fishery cannot be verified by weight tallies, as domestic catches are.

Stock Abundance and Management

Total biomass estimates for Pacific whiting off the west coast of North America were 1,198,932 and 1,537,182 t in 1977 and 1980, respectively (Dark et al. 1980; footnote 3). It was estimated that about 350,000 t and 340,000 t in 1977 and 1980, respectively, were present in the International North Pacific Fisheries Commission (INPFC) Vancouver area, of which the majority would be in the Canadian zone.

While there is little doubt that the numbers of whiting present can support a commercial fishery, there is an unanswered and unstudied question about the desirability of overfishing the larger, older, and predominantly female fish in the Canadian zone. It may be argued that they are all surplus and can be harvested without management. Alternatively, it can be argued that management is necessary because the reproductive potential of this large body of females is high. It is possible that the apparent healthy state of the offshore Pacific whiting population is related to reduced fishing pressure on older fish as a consequence of their northern migration out of the area of intensive foreign effort. Preservation of these older, larger whiting that are predominantly females may be maintaining the reproductive potential of the populations, particularly if the population encounters unfavorable environmental conditions. Excessive removal of these older fish coupled with continued fishing pressure on younger fish might reduce the populations' ability to maintain recruitment, resulting in major declines in abundance. Older fish should be harvested conservatively until more is known about their relative importance in maintaining reproductive potential. Joint management strategies for the resource are currently being developed by Canada and the United States and will be reported elsewhere.

Acknowledgments

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authors sincerely appreciate the cooperation of fishermen in passing on information about whiting and allowing catches to be sampled.

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Results of the Coastal Pacific Whiting, *Merluccius productus*, Surveys in 1977 and 1980

MARTIN O. NELSON and THOMAS A. DARK

Introduction

A major research vessel survey was conducted in 1977 by the National Marine Fisheries Service (NMFS) and cooperating agencies to help assess the status of Pacific whiting, *Merluccius productus*, and other groundfish species, especially important species of rockfish, *Sebastes* spp., in the California to Vancouver Island, B.C., region (Dark et al., 1980; Gunderson and Sample, 1980). This was the first of a triennial series of comprehensive multispecies groundfish surveys, and it was followed by a comparable survey in 1980. Both surveys included bottom trawl and acoustic (echo integrator)-midwater trawl sampling. A primary objective of each year's survey program was to determine the distribution, biomass, and the length-and-age composition of the exploitable portion of the whiting population. This report summarizes methodologies used in those surveys and presents results obtained for Pacific whiting.

Methods

In both years, the surveys were conducted during July through September, a period of the year when Pacific whiting are between their northward feeding migration and southward spawning migration and coastwise movements appear to be relatively localized. In 1977 the survey included the area from Port Hueneme, Calif. (34°08′N) to Kyuquot Sound, Vancouver Island (50°00′N), except that bottom trawl sampling was limited to the area south of Cape Flattery, Wash. (48°30′N). In 1980 the survey began off Santa Cruz, Calif. (36°50′N) and again ended at 50°00′N. The change in geographic range between years was due mainly to changes in the objectives of the rockfish investigations and to the lack of Pacific whiting (other than juvenile fish) south of Santa Cruz. The survey each year included two or more vessels for bottom trawl sampling and a single vessel equipped with echo integrator and midwater trawling systems to sample the off-bottom component of the population. The estimates of abundance generated by the bottom trawl and echo integrator-midwater trawl surveys were considered additive and representative of the total population. Figure 1 shows the survey areas for 1977 and 1980 and International North Pacific Fisheries Commission (INPFC) statistical areas used to summarize the survey data.

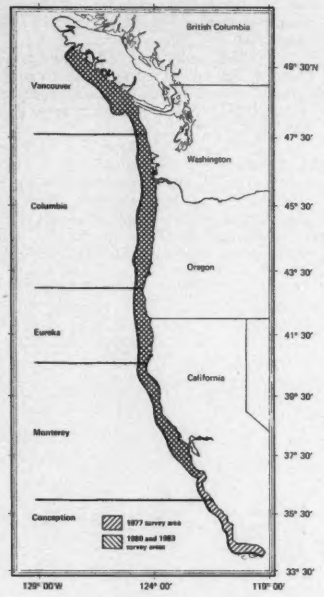

Figure 1.—Areas surveyed in 1977 and 1980, and INPFC statistical areas by which survey data were summarized.

Bottom Trawl Surveys

Methods used in the 1977 bottom trawl surveys are described by Dark et al. (1980) and Gunderson and Sample (1980). The 1980 bottom trawl survey was similar to that conducted in 1977. Sampling effort was again allocated on the basis of target species abundance as indicated by commercial catch statistics, including a special effort to sample whiting most intensively in the area off southern Oregon where the fishery had been focused during 1977-79. Sampling was conducted between depths of 30 and 200 fathoms with stations allocated between two depth strata, 30-99 and 100-200 fathoms. Due to a change in the target rockfish species, sampling of the relatively small 201-260 fathom depth stratum, which had been sampled in 1977, was eliminated; this change was not considered significant because less than 2 percent of the whiting biomass estimate derived from the 1977 bottom trawl survey was located in that depth stratum.

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Biomass estimates were calculated by the "area-swept" method (assuming 100 percent trawl efficiency) and length samples were weighted by catch per unit effort (CPUE) to provide estimates of population length compositions by INPFC areas. Age-length keys were derived by INPFC area and applied to area length frequencies to obtain estimates of population age compositions by INPFC area. Details are presented by Dark et al. (1980). The trawl gear, catch sampling methodology, and abundance and biological parameter estimation procedures used in 1980 were identical to those employed in 1977. Requirements for whiting biological samples in 1980 included the collection of at least 200 otoliths from each depth stratum in each of 12 biological sampling areas described by Dark et al. (1983).

Echo Integrator-Midwater Trawl Surveys

The 1977 echo integrator-midwater trawl survey design and procedures are described by Dark et al. (1980). The 1980 survey was conducted similarly along a zigzag trackline with transects running obliquely across isobaths. The average distance between adjacent transects was 5 n.mi. in 1977, whereas in 1980 it varied between 5 and 7.5 n.mi., depending primarily on observed population densities. In 1980 the shoreward boundary of the survey area was the 30-fathom isobath as opposed to a 50-fathom boundary in 1977, and in both years the seaward boundary was 250 fathoms. Transects were extended if whiting schools were present at the planned bathymetric limits.

The configuration and use of the echo integration system are described by Traynor and Ehrenberg (1979), Dark et al. (1980), and Traynor and Nelson (1981). Echo sign was sampled to identify acoustic targets by species and to collect biological data by using a midwater trawl with a vertical mouth opening of 18-20 m. Codend mesh sizes (stretched measure) in the trawls were 33 mm (1977) and 46 mm (1980). Each trawl haul was directed at selected fish echo targets using a cable netsounder system. Most trawl hauls were made during the day but some trawling was done at night in conjunction with the collection of whiting target strength data, as well as to provide whiting biological samples from areas inadequately sampled during the day. Biological sampling requirements and procedures used for processing trawl catches for species composition data and biological data were not significantly different from those used on the bottom trawl surveys.

The procedures used to derive biomass estimates were basically the same as those described by Dark et al. (1980). Whiting aggregations were identified from the characteristics of their echo signatures and analysis of trawl species composition data. Aggregation boundaries were delineated by examining the distribution of individual (1 min. interval) density (kg/m^2 surface area) estimates along the survey transects. All the echo integrator data for whiting were scaled to estimates of absolute density by assuming an average target strength (i.e., the target strength of the average scattering cross section) of -35 dB/kg for the length range encountered on the surveys. The variance (due to sampling) of each biomass estimate was calculated using cluster sampling techniques in the manner described by Dark et al. (1980) and Williamson (1982).

The length distributions of whiting, by INPFC area, were estimated by combining unweighted midwater trawl length-frequency samples. Age and length keys based on otolith samples were constructed for each INPFC area and applied to the length distributions to provide percentage age compositions. Procedures for developing age-specific biomass and population estimates are still being developed. In this paper, estimates of biomass by age group and INPFC area are presented for 1980.

Estimation of Total Biomass

Total estimates of whiting biomass were made by summing the bottom trawl survey and acoustic survey estimates. Although the acoustic system was capable of sampling to a depth of about 3 m above bottom, target detection actually varied between 3 and 10 m off the bottom, depending on the bottom gradient and other factors. It is highly unlikely the total estimate was substantially increased by the occurrence of whiting in the small interval sampled by both techniques. While the bottom trawl and acoustic surveys were conducted synoptically to the extent possible, we acknowledge the potential for the exchange of bottom and midwater whiting aggregations which could have resulted in some fish being counted by both surveys. Any inflation of biomass estimates due to the "double counting" problem would tend to be compensated by bottom trawl estimates which are considered to be conservative because 100 percent trawl efficiency is assumed.

Distribution and Abundance

Bottom Trawl Surveys

In 1977, the bottom trawl survey covered 37,700 km^2 and included 666 useful hauls (Fig. 2). In 1980, 502 hauls were successfully completed in a 48,722 km^2 survey area (Fig. 3). Estimates of relative abundance, in terms of kilograms caught per kilometer trawled, are shown geographically in Figures 4 and 5. During the 1977 survey, whiting at low densities (<21 kg/km) were distributed much more uniformly than in 1980, but in both years higher densities were very unevenly distributed. Table 1 gives CPUE values by INPFC area and depth, and the most noticeable features are the reduction in CPUE as depth increased and differences in CPUE among INPFC areas. The highest densities were found on the continental shelf (<100 fathoms) in both years. Densities were highest and similar in the Columbia, Eureka, and Monterey areas in 1977, but maximum densities shifted southward in 1980. The extraordinarily high CPUE in the Monterey area in 1980 was due to the presence of a large proportion

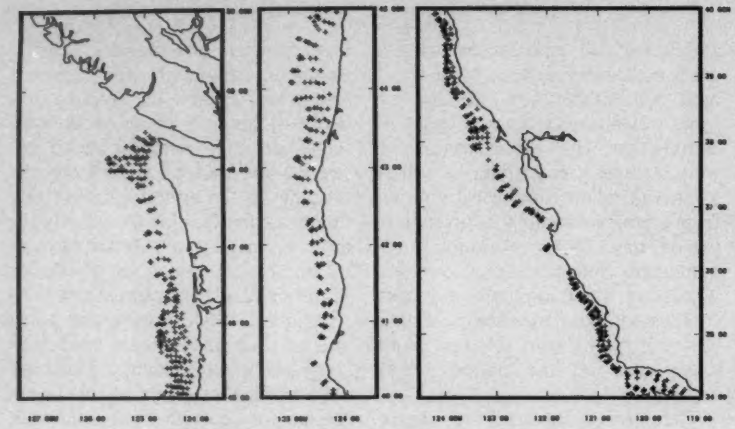


Figure 2.—Geographic distribution of bottom trawl stations in 1977.

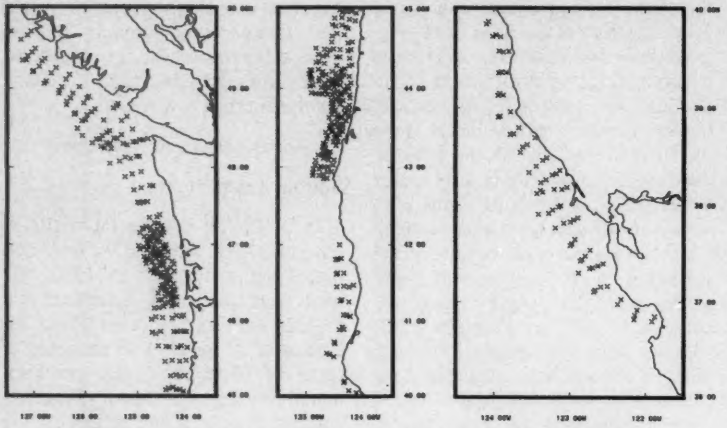


Figure 3.—Geographic distribution of bottom trawl stations in 1980.

Table 1.—The number of bottom trawl hauls and average catch per unit of effort (kg/km) of Pacific whiting by INPFC area and depth stratum for 1977 and 1980.

Year and depth (fathoms)	Vancouver[1]		Columbia		Eureka		Monterey[1]		Conception	
	No. of hauls	kg/km	No. of hauls	kg/km	No. of hauls	kg/km	No. of hauls	kg/km	No. of hauls	kg/km
1977										
50-99	32	19.7	104	42.1	20	48.1	78	36.9	28	7.4
100-149	17	6.9	51	9.0	14	9.0	43	13.8	29	10.5
150-199	14	14.5	33	5.8	13	6.0	44	10.7	19	8.5
200-250	7	2.3	40	5.1	12	1.7	41	4.1	25	1.6
1980										
30-99	65	17.2	249	16.3	24	52.2	56	218.0		
100-200	20	6.1	56	3.6	12	15.2	20	19.6		

[1]As indicated in the text and in Figures 2 and 3, there were significant differences between 1977 and 1980 in the latitudinal extent of the sampling in the Vancouver and Monterey INPFC areas.

of the very abundant 1977 year class. The concentration of these young (age 3) fish in the Monterey area was consistent with the strong tendency for whiting size and age to decrease with latitude.

Between 1977 and 1980, there was a large increase in the biomass of whiting estimated to be available to bottom trawls, and the geographic distribution of biomass changed significantly (Table 2 and Fig. 6). In 1977, the Columbia area contained 47 percent of the estimated biomass; 26 percent of the total was in the Monterey area. The relatively low biomass (6,560 metric tons (t)) in the Vancouver area was partially due to the fact that only a small part of the area was included in the bottom trawl survey. Most of the population in the Conception area was age 0 fish which probably were not sampled representatively. In 1980, 75 percent of the biomass was located in the Monterey area and no other INPFC area contained over 11 percent. In the Monterey area, 77 percent of the estimated population was age 3 fish of the 1977 year class. In both years, most whiting were located on the continental shelf. Only 13 percent and 3 percent of the biomass estimates based on bottom trawl samples for 1977 and 1980, respectively, were found in depths greater than 100 fathoms.

The 95 percent confidence intervals associated with individual INPFC area-depth biomass estimates for 1977 ranged from ± 34 to ± 152 percent of the point estimates and averaged ± 57 percent. In 1980, confidence intervals ranged from ± 45 percent to ± 160 percent with an average of ± 82 percent. The variance of the biomass estimates was higher in 1980 even though the 1980 sampling was designed to increase precision. This is probably largely because the distribution of whiting in 1980 was asynchronous with the survey design, which was based on a predicted distribution derived from fishery statistics.

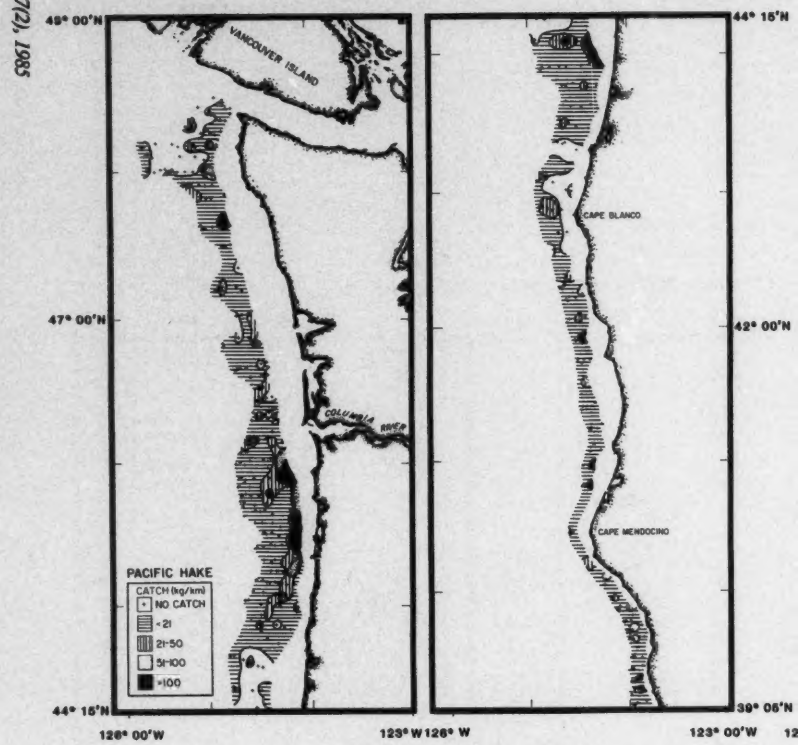
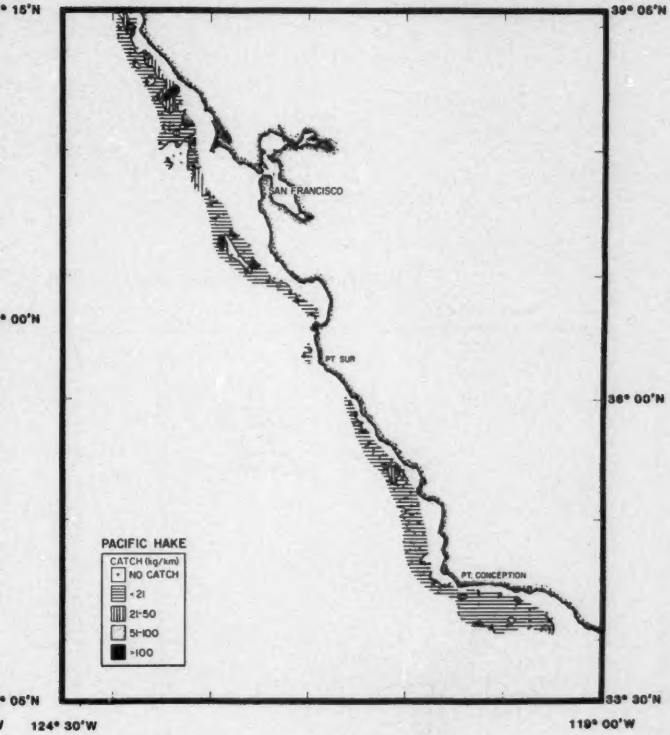
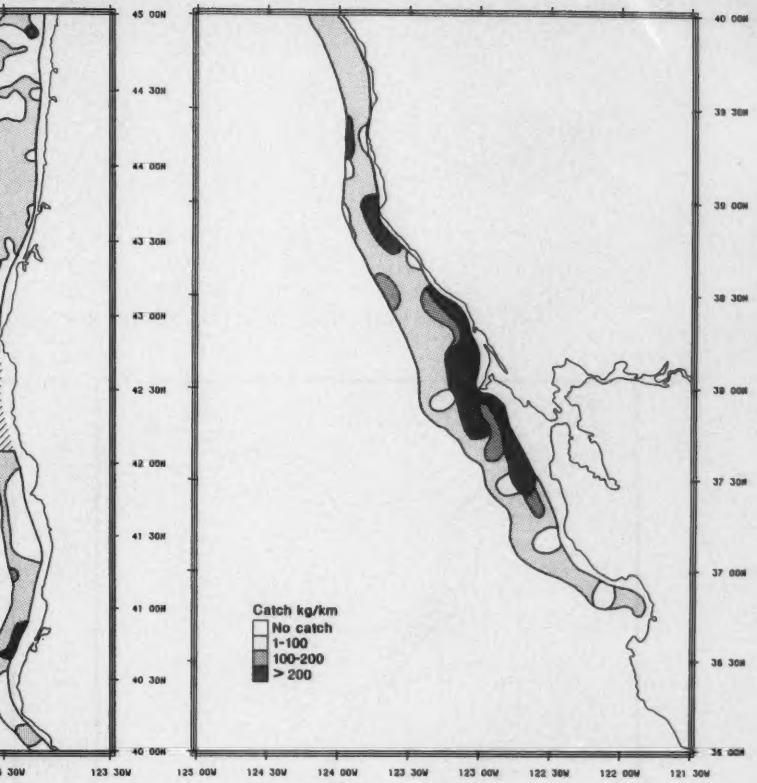


Figure 4.—Pacific whiting density (kg/km) contours as



urs as determined from the 1977 bottom trawl survey.

Figure 5. – Pacific whiting density (kg/km) contours



tours as determined from the 1980 bottom trawl survey.

Table 2.—Estimated biomass (metric tons) and associated 95 percent confidence intervals of Pacific whiting from bottom trawl surveys of 1977 and 1980 by INPFC area and depth stratum.

Year and depth (fathom)	Biomass (t)					
	Vancouver	Columbia	Eureka	Monterey	Conception	Total
1977						
0-99	5,680 ±5,572 (98%)	29,703 ±12,767 (43%)	8,792 ±10,019 (114%)	15,546 ±9,521 (61%)	780 ±410 (53%)	60,501 ±19,251 (32%)
100-149	420 ±310 (74%)	1,592 ±1,072 (67%)	416 ±221 (53%)	1,707 ±2,603 (152%)	953 ±450 (47%)	5,088 ±2,818 (55%
150-199	423 ±281 (66%)	800 ±482 (60%)	227 ±175 (77%)	758 ±656 (87%)	540 ±247 (46%)	2,748 ±879 (32%)
200-250	37 ±30 (81%)	822 ±326 (40%)	66 ±70 (106%)	255 ±86 (34%)	123 ±90 (73%)	1,303 ±348 (27%)
Total	6,560 ±7,873 (120%)	32,917 ±12,951 (39%)	9,501 ±10,223 (105%)	18,266 ±10,036 (55%)	2,396 ±652 (27%)	69,640 ±18,313 (23%)
1980						
30-99	15,976 ±12,157 (76%)	19,093 ±8,550 (45%)	10,689 ±12,059 (113%)	141,449 ±82,624 (58%)		187,207 +84,724 (45%)
100-200	1,310 ±1,205 (92%)	1,063 ±563 (53%)	792 ±1,192 (151%)	2,375 ±1,526 (64%)		5,540 +2,216 (40%)
Total	17,286 ±12,191 (71%)	20,156 +8,631 (43%)	11,481 ±12,171 (106%)	143,824 ±82,855		192,747 ±84,754 (44%)

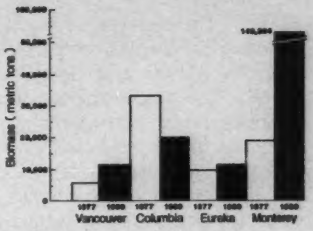


Figure 6.—Bottom trawl survey estimates of Pacific whiting biomass by INPFC area for 1970 and 1980.

Acoustic-Midwater Trawl Surveys

The total distances of the acoustic survey tracklines (Fig. 7, 8) were 6,464 km in 1977 and 4,445 km in 1980. The trackline was shorter in 1980 mainly because of the reductions in geographic coverage and average transect

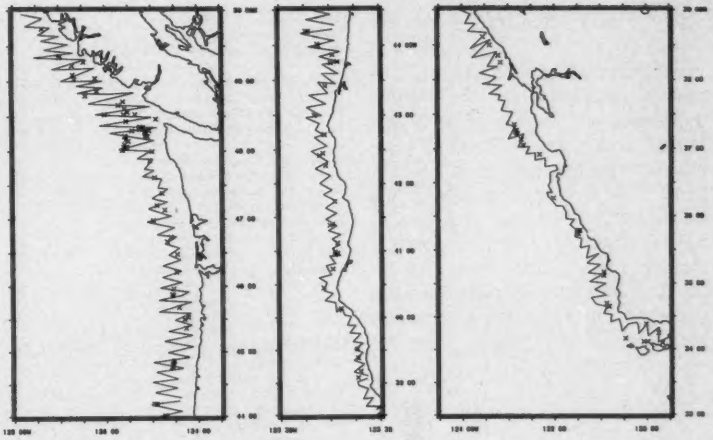


Figure 7.—Acoustic survey trackline and geographic distribution of midwater trawl hauls in 1977.

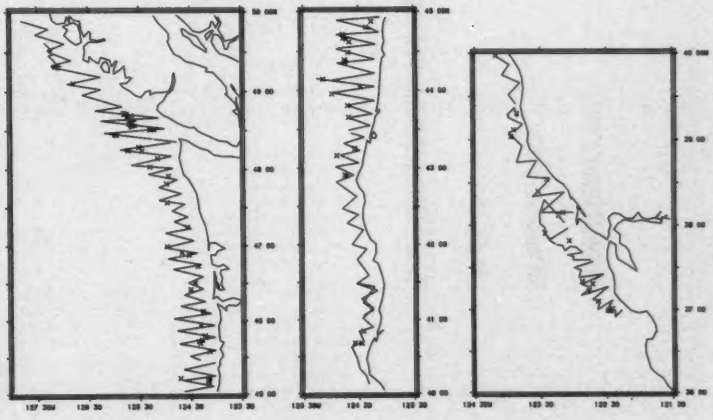


Figure 8.—Acoustic survey trackline and geographic distribution of midwater trawl hauls in 1980.

density. The number of successful midwater trawl hauls completed each year, by INPFC area, is shown in Table 3. The smaller amount of trawl sampling in the Vancouver area in 1980 was largely the result of vessel operation problems which reduced the time available to conduct the survey. This decrease in sampling effort was unfortunate because the number of species which occur in significant quantities in midwater is highest in the Vancouver area and identification and delineation of whiting schools is more difficult than in the other areas. In addition to whiting, the more abundant species in the area include walleye pollock, *Theragra chalcogramma*; Pacific herring, *Clupea harengus pallasi*; spiny dogfish, *Squalus acanthias*; yellowtail rockfish, *Sebastes flavidus*; and redstripe rockfish, *Sebastes proriger* (Table 4).

Estimates of the biomass of the off-bottom component of the whiting population are shown by year and INPFC area in Figure 9 and by year, INPFC area, and subarea in Table 5. In 1977 the biomass estimates for the Vancouver, Columbia, and Eureka INPFC areas were very similar and together they included 90 percent of the total estimate. Biomass estimates were not made for the Conception

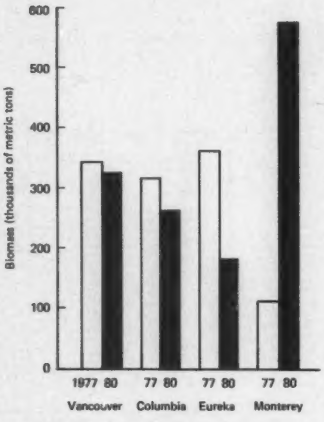


Figure 9.—Acoustic survey estimates of Pacific whiting biomass by INPFC area for 1977 and 1980.

Table 3.—Number of midwater trawl hauls for 1977 and 1980, by INPFC area and bottom depth (fathoms).

INPFC area	No. of hauls, 1977				No. of hauls, 1980			
	50-75	76-100	>100	Total	30-75	76-100	>100	Total
Vancouver	17	19	6	[1]42	8	6	3	17
Columbia	11	11	6	28	6	21	8	35
Eureka	7	6	1	14	2	1	1	4
Monterey	5	2	15	[2]22	9	2	5	16
Conception	2	4	4	10				
Total	42	42	32	116	25	30	17	72

[1]Ten of the 42 hauls were concentrated in a relatively small area off the northern Washington coast during a 5-day cooperative acoustic survey with foreign research vessels.
[2]Four of the 22 hauls were made in that part of the Monterey area not surveyed in 1980.

Table 4.—Percent frequency of occurrence of selected species taken in midwater trawl hauls in 1977 and 1980, by catch size and INPFC statistical area.

Year and species	Catch range (lb)						Catch range (lb)					
	>0		50-499		>500		>0		50-499		>500	
	%	(No.)	%	(No.)	%	(No.)	%	(No.)	%	(No.)	%	(No.)
	Vancouver (42 hauls)						Columbia (28 hauls)					
1977												
Pacific whiting, *Merluccius productus*	83.3	(35)	40.5	(17)	23.8	(10)	96.4	(27)	32.1	(9)	21.4	(6)
Walleye pollock, *Theragra chalcogramma*	61.9	(26)	21.4	(9)	2.4	(1)						
Yellowtail rockfish, *Sebastes flavidus*	71.4	(30)	19.0	(8)	2.4	(1)	42.9	(12)	14.3	(4)	3.6	(1)
Widow rockfish, *Sebastes entomelas*	21.4	(9)	7.1	(3)	4.8	(2)	39.3	(11)			17.9	(5)
Shortbelly rockfish, *Sebastes jordani*							10.7	(3)				
Redstripe rockfish, *Sebastes proriger*	11.9	(5)	4.8	(2)			21.4	(6)	10.7	(3)		
Canary rockfish, *Sebastes pinniger*	11.9	(5)					17.9	(5)				
Chilipepper, *Sebastes goodei*												
Bocaccio, *Sebastes paucispinis*	4.8	(2)					14.3	(4)				
Spiny dogfish, *Squalus acanthias*	50.0	(2)	4.8	(2)	9.5	(4)	14.3	(4)				
Pacific herring, *Clupea harengus pallasi*	42.9	(18)	4.8	(2)	4.8	(2)	14.3	(4)				
Northern anchovy, *Engraulis mordax*							10.7	(3)				
Eulachon, *Thaleichthys pacificus*	50.0	(21)	2.4	(1)			60.7	(12)				
Jack mackerel, *Trachurus symmetricus*	4.8	(2)										
Market squid, *Loligo opalescens*							3.6	(1)				
	Eureka (14 hauls)						Monterey (22 hauls)					
Pacific whiting	85.7	(12)	50.0	(7)	35.7	(5)	86.4	(19)	36.4	(8)	27.3	(6)
Walleye pollock												
Yellowtail rockfish	35.7	(5)					9.0	(2)	4.5	(1)		
Widow rockfish	28.6	(4)	14.3	(2)			9.0	(2)				
Shortbelly rockfish							36.4	(8)			3.6	(3)
Redstripe rockfish	14.3	(2)										
Canary rockfish	21.4	(3)					4.5	(1)	4.5	(1)		
Chilipepper							9.0	(2)	9.1	(2)		
Bocaccio							36.4	(8)	4.5	(1)		
Spiny dogfish	50.0	(7)	14.3	(2)			40.9	(9)	13.6	(3)	4.5	(1)
Pacific herring	7.1	(1)					9.0	(2)				
Northern anchovy												
Eulachon	35.7	(5)										
Jack mackerel	21.4	(3)										
Market squid	14.3	(2)					13.6	(2)	4.5	(1)		
	Conception (10 hauls)						Total (116 hauls)					
Pacific whiting	80.0	(8)	10.0	(1)			87.1	(101)	36.2	(42)	23.3	(27)
Walleye pollock							22.4	(26)	7.8	(9)	0.9	(1)
Yellowtail rockfish							42.2	(49)	11.2	(13)	1.7	(2)
Widow rockfish	10.0	(1)					23.3	(27)	4.3	(5)	6.0	(7)
Shortbelly rockfish	60.0	(6)	10.0	(1)			14.7	(17)	0.9	(1)	2.6	(3)
Redstripe rockfish							11.2	(13)	4.3	(5)		
Canary rockfish							12.1	(14)	0.9	(1)		
Chilipepper	50.0	(5)	10.0	(1)			6.0	(7)	2.6	(3)		
Bocaccio	50.0	(5)					16.4	(19)	0.9	(1)		
Spiny dogfish	50.0	(5)	10.0	(1)			39.6	(46)	6.9	(8)	4.3	(5)
Pacific herring							21.6	(25)	1.7	(2)	1.7	(2)
Northern anchovy			10.0	(1)			6.9	(8)	0.9	(1)		
Eulachon							37.1	(43)	0.9	(1)		
Jack mackerel							4.3	(5)				
Market squid	80.0	(8)	10.00	(1)	10.00	(1)	12.1	(14)	1.7	(2)	0.9	(1)

area because whiting aggregations were not observed, although trawl samples revealed age 0 fish dispersed in scattering layers. The Monterey area estimate was only about one-third as large as that in any of the three more northern INPFC areas. This probably was a reflection of the fact that the whiting population in 1977 was composed primarily of fish that were age 4 or older which are normally distributed north of the Monterey area. There were noticeable differences in abundance within INPFC areas, including a lack of fish in the southern part of the Monterey area (lat. 35°30′-37°00′N) and northern part of the Vancouver area (lat. 49°25′-50°00′N), as well as a distinct decrease in abundance between the southern (lat. 43°00′-45°00′N) and northern (lat. 45°00′-47°30′N) parts of the Columbia area (Table 5).

The amount of change between 1977 and 1980 in the total biomass estimates for the off-bottom component of the population was small compared to that for fish available to bottom trawls (Tables 2 and 5). However, due to the large size of the 1977 year class, there was a similar but somewhat less pronounced geographic shift in abundance between years. The biomass estimate for the Monterey area in 1980 accounted for 43 percent of the total, while only about 10 percent of the total was found there in 1977. Also, it was estimated that over 75 percent of the biomass in the area was composed of 3-year-old fish. North of the Monterey area, the most significant change in abundance occurred in the Eureka area where the biomass estimate decreased by almost 50 percent between 1977 and 1980.

In all INPFC areas during both years, a majority of the biomass of the off-bottom component of the whiting population was found over the continental shelf, i.e., inside the 100-fathom isobath (Fig. 10). The percentage of the total biomass located over the shelf increased from 59 percent in 1977 to 75 percent in 1980. This increase occurred partly because the 1980 survey included depths of 30-50 fathoms, whereas in 1977 that depth zone was sampled

Table 4.—Continued.

Year and species	Catch range (lb) >0 %	(No.)	50-499 %	(No.)	>500 %	(No.)	Catch range (lb) >0 %	(No.)	50-499 %	(No.)	>500 %	(No.)
1980	Vancouver (17 hauls)						Columbia (35 hauls)					
Pacific whiting	70.6	(12)	11.8	(2)	41.2	(7)	85.7	(30)	28.6	(10)	34.3	(2)
Walleye pollock	23.5	(4)	17.6	(3)								
Yellowtail rockfish	70.6	(12)	11.8	(2)	5.9	(1)	28.6	(10)	14.3	(5)		
Widow rockfish	11.8	(2)			5.9	(1)	22.9	(8)	5.7	(2)	5.7	(2)
Shortbelly rockfish							8.6	(3)	2.9	(1)	2.9	(1)
Redstripe rockfish	41.2	(7)			11.8	(2)	5.7	(2)	2.9	(1)		
Canary rockfish	5.9	(1)					11.4	(4)				
Chilipepper												
Bocaccio												
Spiny dogfish	70.6	(12)	35.3	(6)	5.9	(1)	20.0	(7)				
Pacific herring	47.1	(8)	5.9	(1)	5.9	(1)	11.4	(4)				
Northern anchovy							2.9	(1)				
Eulachon	41.2	(7)					28.6	(10)	5.7	(2)		
Jack mackerel							20.0	(7)			2.9	(1)
Market squid							11.4	(4)				
	Eureka (4 hauls)						Monterey (16 hauls)					
Pacific whiting	100.0	(4)	25.0	(1)	75.0	(3)	93.8	(15)	18.8	(3)	50.0	(8)
Walleye pollock												
Yellowtail rockfish	25.0	(1)	25.0	(1)			6.3	(1)				
Widow rockfish	25.0	(1)					6.3	(1)				
Shortbelly rockfish	25.0	(1)					37.5	(6)			18.8	(3)
Redstripe rockfish												
Canary rockfish	25.0	(1)										
Chilipepper	25.0	(1)					31.3	(5)				
Bocaccio							12.5	(2)				
Spiny dogfish	50.0	(2)					37.5	(6)	12.5	(2)	6.3	(1)
Pacific herring							12.5	(2)				
Northern anchovy												
Eulachon												
Jack mackerel							31.3	(5)	6.3	(1)	6.3	(1)
Market squid							50.0	(8)	6.3	(1)		
							Total (72 hauls)					
Pacific whiting							84.7	(61)	22.2	(16)	41.7	(30)
Walleye pollock							5.6	(4)	4.2	(3)		
Yellowtail rockfish							33.3	(24)	11.1	(8)	1.4	(1)
Widow rockfish							16.7	(12)	2.8	(2)	4.2	(3)
Shortbelly rockfish							13.9	(10)	1.4	(1)	5.6	(4)
Redstripe rockfish							12.5	(9)	1.4	(1)	2.8	(2)
Canary rockfish							8.3	(6)				
Chilipepper							8.3	(6)				
Bocaccio							2.8	(2)				
Spiny dogfish							37.5	(27)	11.1	(8)	2.8	(2)
Pacific herring							19.4	(14)	1.4	(1)	1.4	(1)
Northern anchovy							1.4	(1)				
Eulachon							23.6	(17)	2.8	(2)		
Jack mackerel							16.7	(12)	1.4	(1)	2.8	(2)
Market squid							16.7	(12)	1.4	(1)		

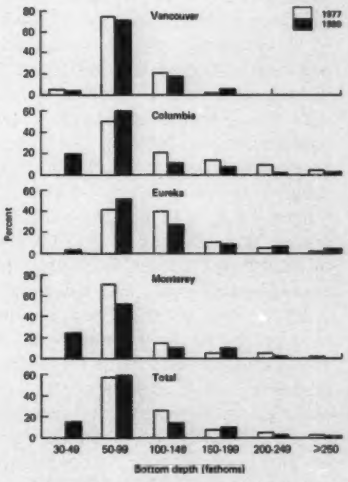


Figure 10.—Distribution by depth, for each INPFC area, of acoustic survey estimates of Pacific whiting biomass for 1977 and 1980.

Table 5.—Acoustic survey estimates of Pacific whiting biomass (t) and associated 95% confidence intervals for 1977 and 1980, by INPFC area and latitudinal subarea.

	1977				1980			
INPFC area	Latitudinal subarea	Biomass (t)	Percent of total	95% confidence interval	Latitudinal subarea	Biomass (t)	Percent of total	95% confidence interval
Vancouver (47°-30'-50°30'N)[1]	48°-25'-49°25'	142,422	12.6	±30,808 (±22%)	48°-11'-49°26'	247,742	18.4	±76,892 (±31%)
	47°-30'-48°25'	201,399	17.8	±77,459 (±39%)	48°-03'-48°10'	17,935	1.3	±28,487 (±16%)
	Area total	343,821	30.4	±83,325 (±24%)	47°-27'-48°00'[3]	56,658	4.7	±26,068 (±46%)
					Area total	322,335	23.9	±86,044 (±27%)
Columbia (43°-00'-47°30'N)	46°-44'-47°30'	15,526	1.4	±10,358 (±67%)	46°-40'-47°23'	76,813	5.7	±13,625 (±18%)
	45°-50'-46°44'	26,776	2.4	±3,415 (±13%)	46°-21'-46°36'	19,802	1.5	±10,172 (±53%)
	45°-00'-45°50'	18,604	1.6	±3,834 (±21%)	45°-41'-46°12'	81,749	6.1	±35,504 (±13%)
	44°-08'-45°00'	55,966	5.0	±14,441 (±26%)	45°-10'-45°20'	9,158	0.7	±2,354 (±26%)
	43°-00'-44°08'	199,568	17.7	±65,879 (±33%)	44°-45'-44°51'	5,516	0.4	±3,038 (±55%)
	Area total	316,440	28.0	±68,276 (±22%)	44°-37'-44°43'	4,614	0.3	±3,460 (±75%)
					43°-57'-43°59'	555	0.1	±482 (±87%)
					43°-51'-43°58'	3,513	0.3	±3,427 (±98%)
					42°-59'-43°35'[3]	58,757	4.4	±20,842 (±35%)
					Area total	260,477	19.4	±44,979 (±17%)
Eureka (40°-30'-43°00'N)	41°-47'-43°00'	169,493	15.0	±47,710 (±28%)	40°-36'-42°00'	182,783	13.6	±45,762 (±25%)
	40°-25'-41°47'[2]	191,451	17.0	±60,156 (±31%)				
	Area total	360,944	32.0	±76,647 (±21%)				
Monterey (35°-30'-40°30'N)[2]	38°-49'-40°16'	58,860	5.2	±20,758 (±35%)	40°-07'-40°15'	3,547	0.3	±2,131 (±60%)
	37°-07'-38°49'	49,227	4.4	±25,705 (±52%)	38°-54'-40°01'	158,534	11.8	±64,184 (±40%)
	Area total	108,087	9.6	±32,949 (±30%)	37°-49'-38°47'	407,225	30.3	±105,354 (±26%)
					37°-45'-37°47'	9,535	0.7	±10,530 (±110%)
					Area total	578,841	43.1	±123,883 (±21%)
	Total	1,129,292	100.0	±136,375 (±12%)	Total	1,344,436	100.0	±163,875 (±12%)

[1]Area between lat 50°00' and 50°30' not surveyed.
[2]Area south of lat. 36°55' not surveyed in 1980.
[3]Includes small part of adjacent INPFC area to south.

only in the northern part of the Vancouver area. Only 7 percent and 3 percent of the total acoustic estimates of biomass for 1977 and 1980 were in depths greater than 200 fathoms.

Because of the survey method's high sampling rate, the estimated precision of the acoustic estimates of biomass was relatively high compared with the precision of bottom trawl based estimates (Table 5). The 95 percent confidence intervals for INPFC subarea biomass estimates in 1977 ranged from ±13 percent to ± 67 percent with a mean of ±33 percent of the point estimate. For 1980, the corresponding range and mean were ±16 percent to ±110 percent and ±51 percent of the point estimate. In 1980 estimates were made for several relatively small concentrations of whiting, and the larger confidence intervals reflect the small sample sizes. In both years, none of the confidence intervals for individual INPFC areas exceeded ± 30 percent. It should be recognized that the confidence intervals provide a measure of the precision of the biomass estimates, but they do not incorporate the effect of variability in the target strength parameter.

Age and Length Composition

Bottom Trawl Surveys

Whiting population-age compositions by INPFC area as determined from the 1977 and 1980 bottom trawl samples are shown in Figure 11. During both years the population in most areas was dominated by one or two year classes and the commonly observed increase in average age with latitude was apparent.

In 1977 4- or 7-year-old whiting, or both, representing the 1973 and 1970 year classes, predominated in four of five INPFC areas. The abundance of these age groups relative to one another is mainly a function of latitude. The very strong 1970 year class (age 7) was the most abundant age group in the Vancouver, Columbia, and Eureka areas. Four-year-old whiting (1973 year class) were the second most abundant age group in the Eureka area and were the dominant group in the Monterey area. The large size of the 1973 year class was further evident in its unusually high abundance in the Vancouver and Columbia areas. The 1977 year class (age 0) was the dominant age group (82 percent) in the Conception area in 1977, but also was about 7 percent of the population in the Monterey area which is indicative of its large size.

In 1980 the whiting population sampled by bottom trawls in the Eureka area and, especially the Monterey area, was completely dominated by 3-year-old fish of the 1977 year class. Even though it was almost absent in the Vancouver and Columbia areas, that year class accounted for about 53 percent of the total biomass estimated by the bottom trawl survey. In the Vancouver and Columbia areas there was no dominant age group. The 3-year-old whiting did not occur in significant numbers that far north, and the strong 1970 and 1973 year classes had

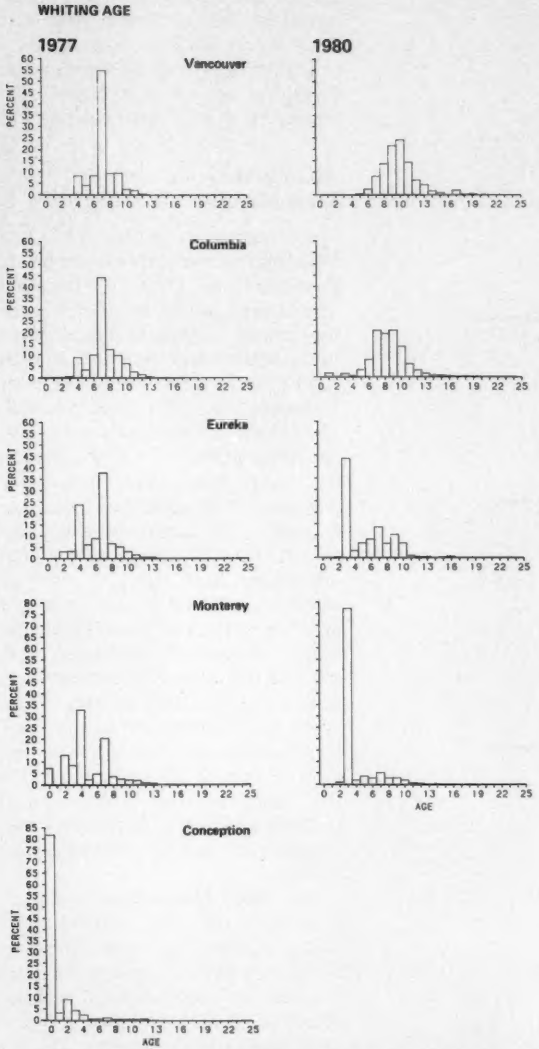


Figure 11.—Age compositions of Pacific whiting by INPFC area for 1977 and 1980, as determined from bottom trawl samples.

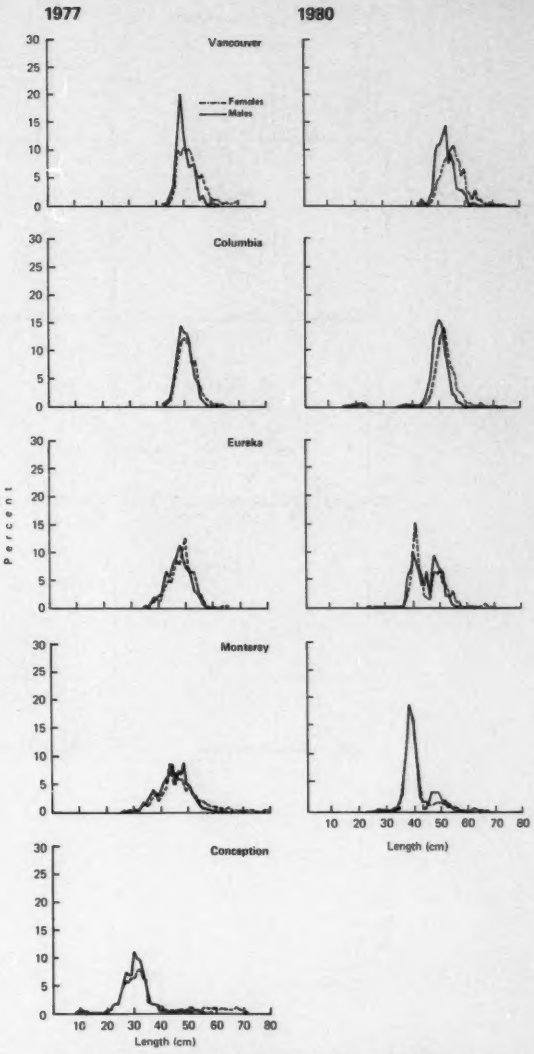


Figure 12.—Length distributions of Pacific whiting for 1977 and 1980, by sex and INPFC area, as determined from bottom trawl samples.

been significantly reduced in size by the effects of fishing and natural mortality.

The length distributions of whiting from bottom trawl samples in 1977 and 1980 (Fig. 12) reflect the more prominent features of the age compositions. In both years, an increase in mean length with latitude is apparent for both sexes, and differences in length range among INPFC areas correspond with changes in the number of age groups represented in the samples. The larger mean length of females in most areas each year is in agreement with growth studies (Dark, 1975) which indicate that after age 3, the average length-at-age of females is greater than that of males. Also, it is apparent that among the larger and older fish, females are

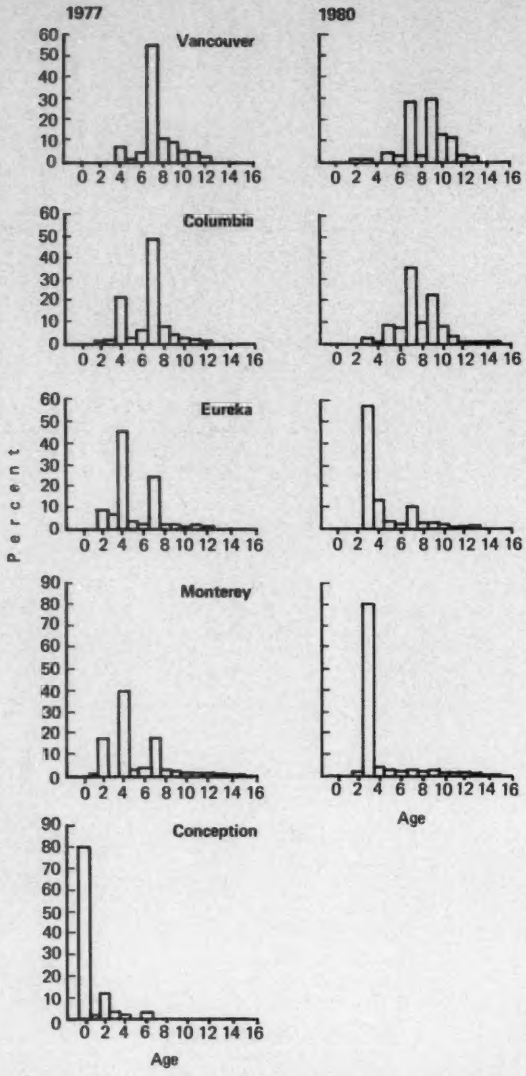


Figure 13.—Age composition of Pacific whiting by INPFC area for 1977 and 1980, as determined from midwater trawl samples.

more abundant. In 1977 there were sharp modes at 50-52 cm in the Vancouver and Columbia areas that were related to the dominance of 7-year-old fish in those areas. In the more southern areas where younger age groups were important, the length modes were less pronounced (except in the Conception area where unsexed age 0 fish (not shown in Fig. 12) were dominant). The 1980 length distributions in the Vancouver and Columbia areas were unimodal, but due to the absence of a dominant age group, the modes were less pronounced than in 1977. Length distributions in the Eureka and Monterey areas were bimodal in 1980 and mean sizes were 2.5.-5.0 cm smaller than in 1977, reflecting the presence of the abundant 3-year-old age group together with smaller numbers of 4- to 10-year-olds.

Acoustic-Midwater Trawl Surveys

Age compositions for 1977 and 1980 from midwater trawl samples are shown in Figure 13. In 1977 the trend in age composition by INPFC area was generally similar to that observed in the bottom trawl samples. In each INPFC area except Conception, 4- or 7-year-olds, or both, predominated. The midwater trawl and bottom trawl age compositions were most similar in the Conception area where the population was dominated by the age 0 group. The most noticeable differences between the age composition determined from the two types of sampling occurred in the Columbia area where 1- and 2-year-old whiting were represented in midwater trawl samples, but absent in bottom trawl samples; in the Eureka area where 4-year-olds dominated in midwater trawl samples instead of 7-year-olds as in the bottom trawl samples; and in the Monterey area where age 0 specimens occurred in bottom trawl samples but not in midwater trawl samples.

The 1980 midwater trawl age compositions for the Eureka and Monterey areas were also similar to those determined from bottom trawl samples, with both types of samples clearly showing the dominance of the 1977 year class in both areas. The importance of this year class is particularly evident in estimates of biomass by age (Fig. 14). In the Vancouver and Columbia areas in 1980, where there was no dominant age group, there was noticeably more variation between the midwater and bottom trawl age compositions. In particular, 8-year-olds were noticeably less abundant in the midwater trawl samples. It is suspected that this difference is due to sampling variability or a bias in age determina-

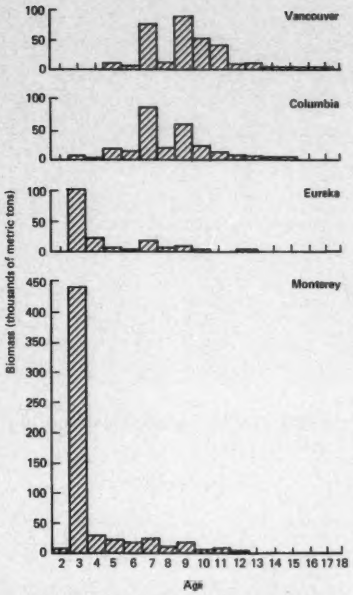


Figure 14.—Acoustic survey estimates of Pacific whiting biomass for 1980, by age and INPFC area.

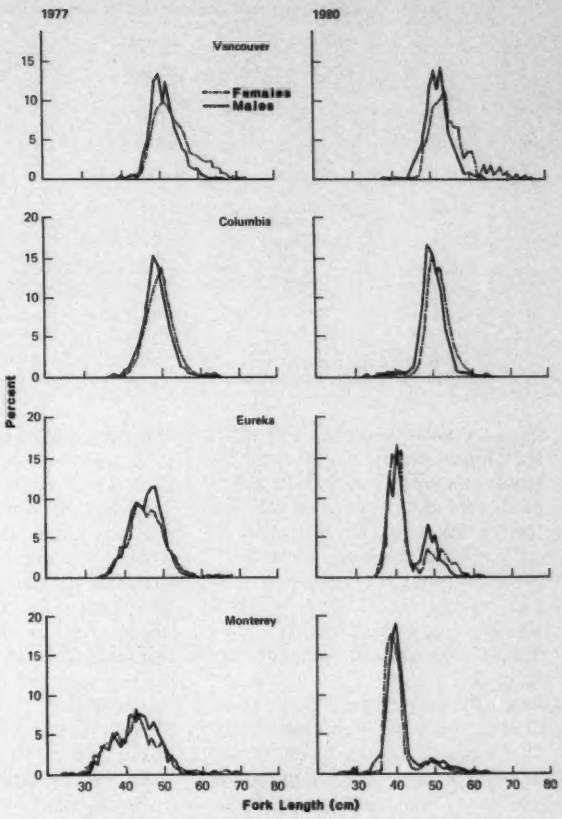


Figure 15.—Length distributions of Pacific whiting for 1977 and 1980, by sex and INPFC area, as determined from unweighted midwater trawl samples.

tions. As in the case of the bottom trawl sample age composition, the strength of the 1973 and 1970 year classes was still apparent in the relative abundance of 7- and 10-year-old fish in the Vancouver-Columbia region. In most instances, the length distributions of midwater trawl samples (Fig. 15) were similar to those of bottom trawl samples, with noticeable differences between the two types corresponding with the more obvious differences in age composition mentioned previously. Although the differences were relatively small, there was a consistent tendency for the mean length of whiting taken in midwater trawl hauls to be less than that in bottom trawl hauls. With the exception of the Vancouver area in 1977 and the Columbia area in 1980 (males only), this difference by gear type occurred for each sex, in each INPFC area, during both years (Table 6).

Table 6.—Mean lengths (cm) of Pacific whiting (male, female, and combined) in bottom trawl and midwater trawl catches by INPFC area for 1977 and 1980.

INPFC area	1977						1980					
	Bottom trawl			Midwater trawl			Bottom trawl			Midwater trawl		
	Male	Female	Comb.	Male	Female	Comb.	Male	Female	Comb.	Male	Female	Comb.
Vancouver	50.4	52.5	51.8	51.4	53.8	53.0	52.8	55.9	55.2	52.0	54.9	53.8
Columbia	50.1	51.6	50.9	48.6	49.8	49.2	49.7	52.0	51.1	49.7	51.2	[1]50.0
Eureka	47.1	48.6	48.0	45.2	45.7	45.4	44.8	45.8	45.3	42.4	43.0	42.7
Monterey	44.2	47.0	[1]43.1	42.7	43.1	42.9	40.6	40.4	40.5	39.8	40.3	[1]39.6

[1]Includes unsexed specimens which were nearly all ≤20 cm.

Total Biomass Estimates

Total whiting biomass estimates were 1,198,932 t and 1,537,183 t in 1977 and 1980, respectively (Table 7). In both years, a very large percentage of the total estimate and the estimates for each INPFC area[1] were derived

[1]Excluding the Conception area in 1977 which had no acoustic estimate.

Table 7.—Combined bottom trawl survey and acoustic survey estimates of Pacific whiting biomass (t) for 1977 and 1980, by INPFC area.

	1977						1980					
	Bottom trawl		Acoustic		Total		Bottom trawl		Acoustic		Total	
INPFC area	t (%)[1]	(%)[2]	t (%)[1]	(%)[2]	t (%)[1]	(%)[2]	t (%)[1]	(%)[2]	t (%)[1]	(%)[2]	t (%)[1]	(%)[2]
Vancouver	6,560 (1.9)	9.4	343,821 (98.1)	30.4	350,821 (100.0)	29.3	17,286 (5.1)	9.0	322,335 (94.9)	23.9	339,621 (100.0)	22.1
Columbia	32,917 (9.4)	47.3	316,440 (90.6)	28.0	349,357 (100.0)	29.1	20,156 (7.2)	10.5	260,477 (92.8)	19.4	280,633 (100.0)	18.3
Eureka	9,501 (2.6)	13.6	360,944 (97.4)	37.0	370,445 (100.0)	30.9	11,481 (5.9)	5.9	182,783 (94.1)	13.6	194,264 (100.0)	12.6
Monterey	18,266 (14.5)	26.2	108,087 (85.5)	9.6	126,353 (100.0)	10.5	143,824 (19.9)	74.6	578,841 (80.1)	43.1	722,665 (100.0)	47.0
Conception	2,396 (100.0)	3.4			2,396 (100.0)	0.2						
Total	69,640 (5.8)	100.0	1,129,292 (94.2)	100.0	1,198,932 (100.0)	100.0	192,747 (12.5)	100.0	1,344,436 (87.5)	100.0	1,537,183 (100.0)	100.0

[1]Percentage by type of survey.
[2]Percentage of total for all INPFC areas combined.

from the acoustic survey. Except for the Monterey area, the bottom trawl estimates were all less than 10 percent of the combined estimates. The difference between the two types of estimates was noticeably less in the Monterey area, particularly in 1980, and suggests that 2- and 3-year-old whiting may be relatively less available to acoustic sampling than older age groups. The exceptionally large difference between the two types of estimates in the Vancouver area in 1977 was partially due to the absence of bottom trawl sampling in most of that area. The distribution of the biomass among INPFC areas was essentially the same as that described previously for the acoustic estimates.

Summary

The results of acoustic and bottom trawl surveys conducted in 1977 and 1980 have provided additional information on the biology and behavior of Pacific whiting. The highly variable year-class strength reported by others (Alverson and Larkins, 1969; Dark, 1975; Bailey et al.,[2]) was observed in both years. The 1973 year class was dominant in 1977, and 3 years later the 1977 year class was extremely abundant. The estimated biomass increased about 28 percent between 1977 and 1980 from 1,129,000 t to 1,537,000 t, primarily due to the recruitment of the 1977 year class. Such variable recruitment not only influences the size of the whiting resource but also affects its coastwide distribution. The center of abundance can occur almost anywhere over about 12 degrees of latitude depending, at least partly, on the age structure of the population. Ten percent of the biomass was in the Monterey area in 1977, but 47 percent was estimated to be there in 1980 when the population was dominated by 3-year-olds.

The coastwide distribution of the bottom component of the population was more uniform in 1977 than in 1980 and in both years most of the resource was located over the continental shelf in waters less than 100 fathoms deep. On the average, 90 percent of the biomass was found to be aggregated in pelagic schools unavailable to the bottom trawls used. The mean size of whiting taken by midwater trawl tended to be slightly smaller than the mean size in bottom trawl samples. This may be a reflection of feeding behavior, with small fish seeking euphasiids and planktonic organisms throughout the water column and large fish focusing their feeding efforts on a greater array of prey species including fish and shrimp found adjacent to the bottom.

Further information about methods and a discussion of the accuracy of biomass estimates and the role of surveys in assessments of Pacific whiting can be found in Nelson and Dark (In press).

[2]Bailey, K. M., R. C. Francis, and P. R. Stevens. 1982. The life history and fishery of Pacific hake *Merluccius productus*. Processed Rep. 82-03, 81 p. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

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History and Management of the Coastal Fishery for Pacific Whiting, *Merluccius productus*

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Introduction

This paper summarizes the history and condition of the west coast fishery for Pacific whiting, *Merluccius productus*, and both reviews and advances some ideas concerning management of the resource. This work results equally from basic biological research, well documented survey and fisheries statistics, mathematical modeling, and a multinational examination of the biological basis for management of the resource. Additional material on these subjects is presented by Francis et al.[1]

The West Coast Stock and Fishery

Catch History

Pacific whiting has been the target of a large foreign fishery off the west coast of the United States and Canada (Table 1). A Soviet fishery for whiting began in 1966 with a catch of 137,000 metric tons (t). From 1973 to 1976 Poland, the Federal Republic of Germany (West Germany), the German Democratic Republic (East Germany), and Bulgaria joined the fishery. Reported catches peaked in 1976 at 237,500 t. Reductions in catch in recent years in U.S. waters have been due primarily to severe restrictions on foreign effort imposed subsequent to the implementation of the Magnuson Fisheries Conservation and Management Act (MFCMA) of 1977.

In U.S. waters, a small fishery for whiting has existed since at least 1879 (Jow, 1973). With the exception of 1967, the fishery has been rather insignificant, with catches in the range of 100-1,100 t/year. However, in recent years joint venture fisheries for whiting have become important in both U.S. and Canadian waters.

The fishery is tied closely to the migratory movements of the whiting population. Most years, the fishery begins in waters off northern California and southern Oregon in April and moves northward as schools migrate in a northerly direction during the summer (Bailey et al., 1982). The fishery in Canadian waters generally starts in July or early August (Beamish and McFarlane, 1985). In all areas the fishery usually ends in mid to late October with the offshore and southerly movement of the fish back to the winter spawning grounds.

Table 1.—Annual catches of foreign, joint venture, and domestic fisheries (in kilotons) of Pacific whiting in U.S. and Canadian waters and estimates of effort (1,000 standard days) for total fishery, 1966-83.

	U.S.				Canada				Combined		
Year	Foreign	Joint Venture	Domestic	Total[1]	Foreign	Joint Venture	Domestic	Total[2]	Total	CPUE[3]	Eff.[4]
	Kilotons										
1966	137.000		0.000	137.000	0.700			0.700	137.700	19.2	7.171
1967	168.699		8.959	177.658	36.713			36.713	214.371	36.0	5.951
1968	60.660		0.159	60.819	61.361			61.361	122.180	11.8	10.397
1969	86.187		0.093	86.280	93.851			93.851	180.131	18.5	9.726
1970	159.509		0.066	159.575	75.009			75.009	234.584	25.6	9.160
1971	126.485		1.428	127.913	26.699			26.699	154.612	17.5	8.842
1972	74.093		0.040	74.133	43.413			43.413	117.546	15.9	7.381
1973	145.241		0.072	145.313	15.125		0.001	15.126	160.439	23.8	6.752
1974	194.108		0.001	194.109	17.146		0.004	17.150	211.259	24.3	8.705
1975	205.654		0.002	205.656	15.704			15.704	221.360	19.0	11.646
1976	231.331		0.218	231.549	5.972			5.972	237.521	25.7	9.242
1977	127.013		0.489	127.502	3.453			3.453	130.955	30.9	4.244
1978	96.827	0.856	0.689	98.372	4.650	1.814		6.464	104.836	35.2	2.980
1979	114.909	8.834	0.937	124.680	7.900	4.233	0.302	12.435	137.115	26.0	5.276
1980	44.023	27.537	0.792	72.352	5.273	12.214	0.097	17.584	89.936	28.5	3.152
1981	70.365	43.556	0.839	114.760	3.919	17.159	3.283	24.361	139.121	28.3	4.915
1982	7.089	67.464	1.024	75.577	12.479	19.676	0.000	32.155	107.732	30.9	3.489
1983	0.000	72.100	1.050	73.150	13.117	27.657	0.000	40.774	113.924		
Mean				127.022				29.385	156.407		7.003

[1]1966-80 from Bailey et al. (1982), 1981-82 from PacFin data base; Pacific Marine Fisheries Commission.
[2]Reported by G. A. McFarlane (6-9-83).
[3]1966-81 from Bailey et al. (1982) for U.S. fishery; 1982 estimated from Bulgarian fleet in U.S. waters.
[4]Estimated assuming CPUE (Canada) = CPUE (U.S.).

[1]Francis, R. C., G. A. McFarlane, A. Hollowed, G. L. Swartzman, and W. M. Getz. 1984. Status and management of the Pacific hake (*Merluccius productus*) resource and fishery off the west coast of the United States and Canada. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd. E., Seattle, WA 98112. Proc. Rep. 84-18, 73p.

The authors are with the Resource Ecology and Fisheries Management Division, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., BIN C15700, Building 4, Seattle, WA 98115.

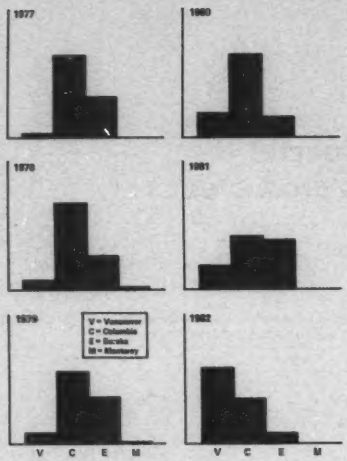

Figure 1.—Relative distribution of Pacific whiting catch in weight by INPFC area.

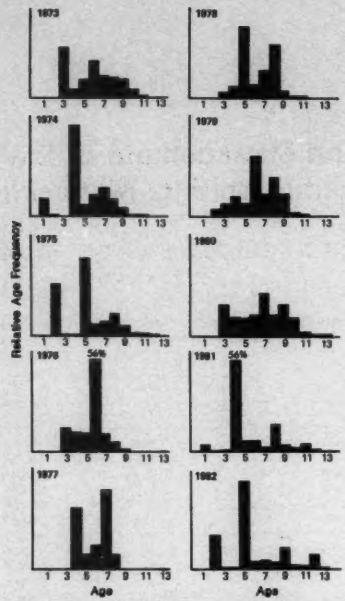

Figure 2.—Relative age-frequency of Pacific whiting catch in U.S. waters, 1973-82.

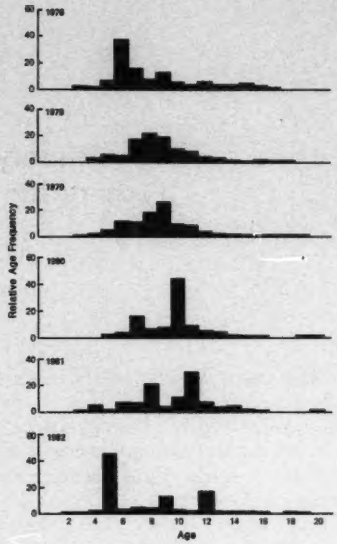

Figure 3.—Relative age-frequency of Pacific whiting catch in Canadian waters, 1976, 1978-82.

Table 2.—Contribution (percent catch by numbers) of fish of the strong 1970, 1973, and 1977 year classes to the Pacific whiting fisheries in the U.S. and Canadian zones.

Country and year class	Fishing Year						
	1976	1977	1978	1979	1980	1981	1982
U.S.							
1970	57	38	27	12	8	4	4
1973	10	30	36	30	21	13	10
1977				4	16	56	45
	—	—	—	—	—	—	—
Total	67	68	63	46	45	73	59
Canada							
1970	36		22	26	44	29	19
1973	3		6	11	16	21	14
1977						5	43
	—		—	—	—	—	—
Total	39		28	37	60	55	76

Figure 1 gives the distribution of catch by International North Pacific Fisheries Commission (INPFC) statistical areas for 1977-82. Recently the largest removal has been from the INPFC Columbia area (with the exception of 1982 when the fishery was forced north due to a preponderance of small unmarketable fish south of the INPFC Vancouver area).

Figures 2 and 3 give the relative age frequencies of catches in U.S. (1973-82) and Canadian (1976, 1978-82) waters respectively. The age at which most fish are first recruited to the U.S. fishery is 2 or 3 years, whereas most fish are recruited to the Canadian fishery at age 5 or 6. Strong year classes clearly dominate the fisheries in both U.S. and Canadian waters (Table 2). Currently, the 1970, 1973, and 1977 year classes are dominant in the fishery. In 1982, these three year classes accounted for 59 and 76 percent of the estimated catches by age in the U.S. and Canadian zones, respectively. Indications are that the 1980 year class, not yet fully recruited to either the U.S. or Canadian fisheries, may be one of the strongest year classes ever observed in the fishery (T. A. Dark[2]). During the history of the fishery, it is apparent that strong year classes have occurred in 1980, 1977, 1973, 1970, 1967 or 1968, 1964, and 1961 (Beamish and McFarlane, 1985).

Bailey (1981, 1982) and Bailey and Francis (1985) document the current state of knowledge of early life history and its effects on subsequent recruitment in Pacific whiting. Their studies point to conditions during the first few months of life as being critical in determining year-class strength.

The mean size of males and females from the 1970 year class sampled in the U.S. and Canadian commercial fisheries from 1976 through 1982 is compared in Figure 4. It shows that not only do larger, older fish tend to occur in the Canadian fishery, but the individuals of any particular year class tend to stratify on a north-south gradient by size, with the larger fish occurring farther north. In addition, Beamish and McFarlane (1985) indicate that females dominate the catch in the Canadian zone, ranging from

[2]T. A. Dark, Northwest and Alaska Fisheries Center, Natl. Mar. Fish. Serv., NOAA, 2725 Montlake Blvd., E., Seattle, WA 98112. Pers. commun. 1984.

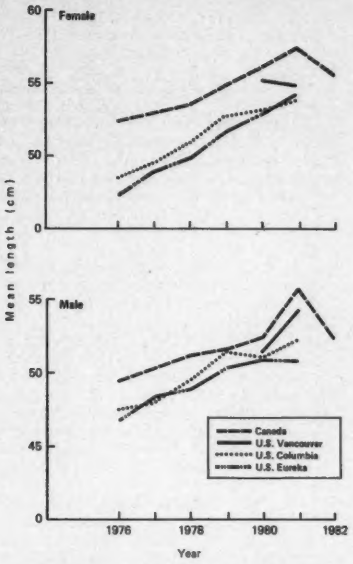

Figure 4.—Mean size of female and male Pacific whiting from the 1970 year class in the U.S. and Canadian fisheries from 1976-82.

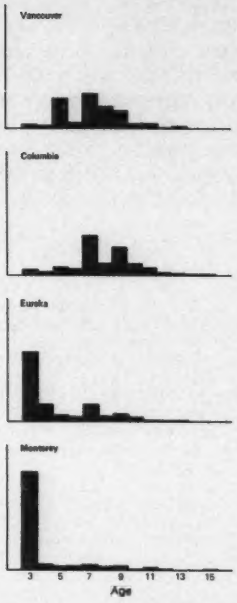

Figure 5.—Relative age-frequency of Pacific whiting in the 1980 NWAFC trawl-hydroacoustic survey of the Northwest and Alaska Fisheries Center.

Table 3.—Distribution of Pacific whiting biomass (kilotons) from two (1977 and 1980) Northwest and Alaska Fisheries Center trawl-hydroacoustic surveys[1] from International North Pacific Fisheries Commission (INPFC) Monterey area and northward.

Year and Survey type	INPFC area				
	Vancouver	Columbia	Eureka	Monterey	Total
1977					
Midwater	343.821	316.440	360.944	108.087	1129.292
Bottom	6.560	32.917	9.501	18.266	67.244
Total	350.381	349.357	370.445	126.353	1196.536
1980					
Midwater	322.335	260.477	182.783	578.841	1344.436
Bottom	17.286	20.156	11.481	143.824	192.747
Total	339.621	280.633	194.264	722.665	1537.183

[1]Target strength = −35 decibels.

60 to 82 percent of the catch since 1977.

Biomass Estimates

Numerous direct estimates of the biomass of the coastal stock of Pacific whiting have been made and are referenced by Bailey et al. (1982). The most reliable estimates of stock biomass are obtained in the triannual National Marine Fisheries Service (NMFS) trawl/hydroacoustic groundfish survey of the west coast region (Dark et al., 1980; Nelson and Dark, In press). Table 3 shows estimates of stock biomass by INPFC statistical area for the two comprehensive surveys run and reported to date (1977 and 1980), and Figure 5 shows estimates of relative age-frequency (ages 3+) by INPFC area for the 1980 survey. All of these demonstrate the size and age stratification of Pacific whiting on the north-south gradient.

The most common indirect method for estimation of available stock biomass is cohort analysis using a time series of catch-at-age data. Francis (1983) describes a weighted cohort analysis procedure used for whiting. He reports markedly different results, especially in terms of estimates of stock biomass, between estimates made under the assumption of constant age-specific natural mortality (M) and those made under the assumption of variable age-specific natural mortality. Using the 1977 and 1980 Northwest and Alaska Fisheries Center (NWAFC) trawl-hydroacoustic survey estimates of stock biomass as validation criteria, indications are that a variable age-specific representation of M is more realistic. Results of the most recent cohort analysis are given in Francis et al. (footnote 1).

Management

Prior to the implementation of the Magnuson Fisheries Conservation and Management Act (MFCMA) in 1977, foreign fisheries off the U.S. west coast were managed by bilateral agreements. From 1977 to 1982, U.S. management was directed by a Preliminary Management Plan (PMP) for groundfish prepared by the Department of Commerce. Subsequently, the Pacific Fishery Management Council (PFMC) has prepared a fisheries management plan (FMP) for groundfish, including whiting, which was implemented in September 1982. Under the plan, the whiting resource

in the U.S. zone is managed under the assumption that:

1) Maximum sustainable yield (MSY) is attainable;

2) For the entire resource (U.S. and Canada), MSY ranges from 120,000 to 270,000 t with a mean value of 195,000 t;

3) 90 percent of the fishable resource is available to the U.S. fishery and 10 percent to the Canadian fishery.

The implication is that MSY in the U.S. zone ranges from 108,000 to 243,000 t with a mean value of 175,500 t.

Canadian management of whiting (Stocker, 1981) is presently based on U.S. stock assessments but does not entirely reflect current U.S. management.

When combined, current U.S. and Canadian allowable catches total 210,000 t, exceeding the present U.S. estimate of MSY by 15,000 t. This reflects a higher estimate (17 percent) of the proportion of the fishable resource available to the Canadian fishery than that stated in the U.S. management plan (10 percent).

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Bailey, K. M. 1981. Larval transport and recruitment of Pacific hake, *Merluccius productus*. Mar. Ecol. Prog. Ser. 6:1-9.

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_____, and _____. In press. Environment and population dynamics of Pacific whiting, *Merluccius productus*. Int. North Pac. Fish. Comm., Bull.

_____, _____, and P. M. Stevens. 1982. The life history and fishery of Pacific whiting, *Merluccius productus*. Calif. Coop. Oceanic Fish. Invest. Rep. 23:81-98.

Beamish, R. J., and G. A. McFarlane. 1985. Pacific whiting, *Merluccius productus*, stocks off the west coast of Vancouver Island, Canada. Mar. Fish. Rev. 47(2):75-81.

Dark, T. A., M. O. Nelson, J. Traynor, and E. Nunnallee. 1980. The distribution, abundance, and biological characteristics of Pacific whiting, *Merluccius productus*, in the California-British Columbia region during July-September 1977. Mar. Fish. Rev. 42(3-4):17-33.

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Jow, T. 1973. Pacific whiting length frequency at California ports, 1963-1970. Calif. Dep. Fish Game, Mar. Res. Tech. Rep. 2.

Nelson, M. O., and T. A. Dark. In press. The distribution, abundance, and biological features of the Pacific whiting resource based on the results of 1977 and 1980 research vessel surveys. Int. North Pac. Fish. Comm., Bull.

Stocker, M. (Editor). 1981. Groundfish stock assessments off the west coast of Canada in 1981 and recommended total allowable catches for 1982. Can. Manuscr. Rep. Fish. Aquat. Sci. 1626, 282 p.

Calendar of Events

November-December 1985

20-24 Nov. Food Fest '85. Hong Kong Exhibition Center, Hong Kong. SHK International Services, Ltd. Third Floor Admiralty Centre Tower II, Hong Kong, telephone 5-8225505.

20-21 Nov. Sea Fare Southeast '85. International Seafood Exposition, Buena Vista Palace, Orlando, Fla. Sea Fare Expositions, Inc., 4016 Ashworth N., Seattle, WA 98103, telephone 206-547-6030.

27 Nov.-3 Dec. SAPEHDAK. Senegalese Exhibition for Agriculture, Fisheries, Animal Husbandry, and Hydraulics. Sofidak, BP 3329, Route de l'Aeroport de Yoff, Dakar, Senegal.

4-6 Dec. USIFS '85. Los Angeles Convention Center, Los Angeles, Calif. Andry Montgomery, Inc., 116 East Blithedale Ave., Mill Valley, CA 94941, telephone 415-381-8206.

4-6 Dec. Fish Pacific. Seattle Center Exhibition Hall, Seattle, Wash. National Fishermen Expositions, P.O. Box 7437, Portland, ME 04112.

January-February 1986

9-12 Jan. International Work Boat Show. New Orleans, La. H. L. Peace Expositions, Inc., P.O. Box 2400, Covington, LA 70434, telephone 504-893-2930.

14-16 Jan. Tropical and Subtropical Fisheries Technologists 11th Annual Meeting. International Airport Holiday Inn, Tampa, Fla. John Koburger, 449 Food Science Building, University of Florida, Gainesville, FL 32611.

23-26 Jan. 12th Annual East Coast Fisherman's Trade Exposition, Ocean City, Md. Betty Duty, MWA, 48 Maryland Ave., Annapolis, MD 21401, telephone 301-268-7722.

11-12 Feb. Seafare '86. Disneyland Hotel, Anaheim, Calif. Seafare Expositions, telephone 206-547-6030.

17-19 Feb. Pacific Fisheries Technologists 1986 Annual Meeting. Westin Bayshore, Vancouver, B.C. J.S. McMillan Fisheries Ltd., 2199 Commissioner Street, Vancouver, B.C., V5L 1A4, telephone 604-255-5191.

25-27 Feb. Infofish Tuna Trade Conference. Bangkok, Thailand. FAO-INFOFISH, P.O. Box 10899, 50728 Kuala Lumpur, Malaysia, Telex INFISH MA 31560.

26 Feb.-2 Mar. Shrimp World II. Maui, Hawaii (shrimp marketing conference). Shrimp World II, 417 Eliza Street, New Orleans, LA 70114, telephone 504-368-1571.

March

8-13 Mar. Alimentaria '86 (Salon International de la Alimentacion). Barcelona, Spain. John Kosmark, Seafood USA, telephone 301-266-5530.

9-13 Mar. Symposium on Common Strategies of Anadromous and Catadromous Fishes. Park Plaza Hotel, Boston, Mass. Robert A. Rulifson, Symposium Secretary, Institute for Coastal and Marine Resources, East Carolina University, Greenville, NC 27834.

11-13 Mar. Seafood '86. World Trade Center, Boston, Mass. Denex International, telephone 207-832-6346.

16-21 Mar. 51st North American Wildlife and Natural Resources Conference. MGM Grand Hotel, Reno, Nev. Larry Jahn, Vice President, Wildlife Management Institute, 1101 14th Street, N.W., Suite 725, Washington, DC 20005.

20-22 Mar. Fishing '86. Scottish Exhibition Center, Glasgow, Scotland. AGB Heighway Ltd., 87 Blackfriars Road, London, England, SE1 8HB.

24-29 Mar. CHEMRAWN IV. Conference on the Global Ocean: Its Chemistry and Resources, Minerals, Food, Drugs, Chemicals, Technology. P. A. Meyers, Department of Atmospheric and Oceanic Science, University of Michigan, 2455 Hayward Ave., Ann Arbor, MI 48109, telephone 313-763-2316.

June-October

17-21 June. The Total Fish Show. Bella Center, Copenhagen, Denmark. ITF International Ltd., Radcliffe House, Blenheim Court, Solihull, West Midlands, England B91 2BG, telephone 021-705-6707.

10-15 Aug. Institute of Fisheries Economics and Trade in Conjunction with the Symposium of Groupe d'Etude des Resources Maritimes Third Conference. University of Quebec at Rimouski, Canada. Sharon Kelly, IIFET, Oregon State University, Corvallis, OR 97331, telephone 503-754-2942.

21-23 Oct. Third International Salmon Symposium, Biarritz, France. Alex Prichard, Courtleigh Manor, Sunningdale, Berkshire, England SL5 9QH.

Note: Listing of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service.

Providing Service to the Seafood Industry Through Market News

DONALD R. WHITAKER

Preface

Probably few businesses are subject to greater threats to profitability than the seafood industry. There are myriad fishing regulations, inspection laws, quotas, gluts, shortages, wide price fluctuations, competition from other protein foods, processing regulations, and every conceivable hindrance to the orderly marketing of a food product.

The seafood industry is probably the last U.S. industry which has as its foundation the hunting and gathering of creatures in the wild. Unlike farming, and industry that has most production sources under control, except for the weather, the seafood industry faces uncertainties that would unnerve most businessmen. Take, for example, the natural cycle of the industry's raw material, the live sea products. Despite vast amounts spent on research, there is no way to predict, on a short-term business basis, whether a good run of fish is going to occur. The problem is equally serious for both the fisherman and the processor. Yet it is hard to imagine the fruit and vegetable industry operating under such uncertain conditions. The agriculture industry has more influence and control of its supply by knowing what acreage is planted, the yield to be expected, and contracts for production from so many acres.

For 47 years the Commerce Department's National Marine Fisheries Service (NMFS)[1], a National Oceanic and Atmospheric Administration agency, has recognized that the seafood business is an inherently unstable business which often requires Government action to supply information to the producers, processors, and the rest of the marketing chain by providing the Market News Service to the seafood industry.

Introduction

The Fishery Market News Program is carried out under the authority of the Agricultural Marketing Act of 1946. The service provides local, regional, national, and international market information. The information is current and covers supply, movement, contractual agreements, inventories, and prices at specific markets for practically all seafood commodities. The marketing of fishery products is characterized by a series of decision points through which product flow concentrates and transactions take place. Market News provides those engaged in the production and marketing of fish products, as well as those supplying the fishing market, with timely, accurate, and unbiased market information. Thus, on a day-to-day basis, those interested in market conditions are in a position to make the critical decisions of where and when to sell, and at what price.

Market information is obtained through joint Federal/industry efforts. Federal Market News reporters visit markets or gather data by telephone. Information and detailed data collected by these reporters are analyzed and immediately disseminated to the seafood community by automatic telephone, current printed reports, Western Union, and radio spots.

The Fishery Market News Service is first and foremost a service-oriented program. Market News is in the forefront of the effort to make Government programs meet the most strenuous of all tests—the market test—by offering its services to users and letting their payment for services reflect part of the value of the program to the marketplace. Because of this, Market News must maintain a high quality of service and remain completely unbiased.

The most important contribution of the Market News Service to the seafood industry is the reduction of risk in the marketing of sea products. The industry's risk factor is among the highest of any section of the U.S. economy. For the industry to make full use of the information provided, it must have unbiased, accurate, and timely information on market conditions throughout the country, and increasingly, in international markets. The Fishery Market News Service provides the seafood industry with the information necessary for successfully reducing marketing risks.

The program gives everyone in the marketing chain a fair shake. It helps the fishermen keep a finger on the pulse of the marketplace. It helps buyers and sellers know what is happening and enables them to deal with markets throughout the country. Market News is, in effect, a third party referee in the marketplace, and as such, it observes, records, and reports market conditions. It is a service agency. The services as referee make possible reduced costs for all levels of the marketing process. In this capacity, it contributes to many Department of Commerce goals as will be seen later.

Market News Purpose

A primary function of the Fishery Market News Service is to provide accurate and unbiased reports depicting current conditions on supply, demand, price, trend, movement, and

[1]Earlier named the Bureau of Commercial Fisheries (BCF), and once a part of the Interior Department's U.S. Fish and Wildlife Service.

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other pertinent information affecting the trade in fish and fishery products. Timely and equal access to the latest market information and statistics is provided to those who want the information (i.e., fishermen, shippers, packers, dealers, processors, importers, wholesalers, and retailers), to help them decide the best time and the best place to buy and sell their products.

This information provides the industry with tools to determine where and when to buy and sell. Market reports assist producers in their production planning and help promote orderly marketing by placing producers and others in the industry on a more equal bargaining basis. Related industries which process and distribute seafood products also make considerable use of market reports to conduct and plan business operations. Market News Reports also reflect the consumer's preference back through marketing channels to producers. Statistics prepared by the Service are used by all segments of the industry and as basic data by Sea Grant colleges, universities, Government agencies, and private research organizations.

The Market News Service proposes to stay abreast of changing patterns in the market and continues to compile and disseminate information which aids producers, consumers, and distributors in the sale and purchase of fishery products.

The Concept

The Market News Service answers the needs of many phases of the marketing process. Reports are:

Impartial—An unbiased third party (a Federal government employee) gathers the information and evaluates it. Neither buyer nor seller has control over the information.

Current—The information gathered is disseminated as rapidly as possible.

Reliable—The market or area of the country to which market news information applies is identified in each report. When possible, the entire spectrum of prices is included, showing a range of prices. Information is frequently verified by double-checking two or more sources before it is released.

Confidential—Information provided by individual firms is combined with that from other firms before it is issued, to insure that no confidential information is released. Virtually all firms contacted by Market News reporters respond freely, with complete confidence that their information will not be used in any way that would disclose their individual operations.

Market News takes the pulse of the market. Other services may try to diagnose the market, but Market News merely observes, records, interprets, and reports. It does not interfere with the operation of the market, although it may influence the decision of buyers, sellers, and others. The role of spectator is intrinsic to Market News. It has become the "eyes and ears" of the seafood industry.

Authority

Market News was first mentioned in U.S. legislation in the 1937 bill which provided the Commerce Department's Bureau of Fisheries appropriations for the start up of Market News in 1938.

Aside from the annual appropriations for running the Market News Service, the basic authority in law for fishery market news operations is found in the Agricultural Marketing Act of 1946 (7 U.S.C. 1621-1927). Section 1622(g) deals with the collection and dissemination of marketing information. Section 1622(k) specifically was concerned with the collection and dissemination of marketing statistics. In section 1626 on definitions it states, "when used in the chapter, the term 'agricultural products' includes . . . fish and shellfish, and any products thereof, including processed and manufactured products."

On 22 March 1958, (23 F.R. 2304), the Director of the Bureau of the Budget transferred all functions of the Department of Agriculture which pertained to fish and shellfish (performed under 7 U.S.C. 1621-1627) to the Department of Interior consistent with various provisions of the Fish and Wildlife Act of 1956.

The Fish and Wildlife Act of 1956, as well as several other acts, does not specifically mention Market News. However, it details responsibilities of the Secretary which could not be conducted without the use of the data and information gathered by Market News. For example, under this Act the Secretary is authorized to disseminate information concerning the production and flow to market of fishery products. In a similar vein, the Saltonstall-Kennedy Act of 1954 (15 U.S.C. 713c-3) made funds available to promote the free flow of domestically produced fishery products.

Getting back to the Fish and Wildlife Act, the Secretary was to study the economic condition of the industry and to develop promotional and informational activities to stimulate consumption. This work could not be undertaken without knowledge of market prices and market data reported by Market News.

The Magnuson Fishery Conservation and Management Act of 1976 (16 U.S.C. 1801-1882) established eight Regional Fishery Management Councils to develop fishery management plans. Each plan has a section discussing the economics and the status of the industry. Market News data is always used in preparing this section of the plan.

The Secretary of Agriculture is authorized to make acquisition and disposal of surplus fishery products under 15 U.S.C. 713c-2, 15 U.S.C. 713c-3, 7 U.S.C. 612c and 16 U.S.C. 742e. In making recommendations to the Secretary regarding purchases of fishery products, Market News again is always used.

The Department of Commerce has 20 major goals to direct its most important activities. Of the 20, the Market News Service contributes to 9 of the goals. These are:

1) Establish trade expansion as a major national priority.

Market News Capsule History

1937
The first session of the 75th Congress passed a Bureau of Fisheries appropriation with an amendment which provided for and established a Fishery Market News Service. The first Fishery Market News office was opened in New York City in November.

1938
The first daily report was issued in New York City on 14 February, a location chosen because it was the largest and most important wholesale fish market in the country.
The second Market News office was opened in Boston, Mass., in May. Boston was chosen because of its importance as a fishing port, fish-processing center, distribution center, and proximity to such other New England fishing ports as Gloucester, New Bedford, and Provincetown, Mass.; and Portland and Rockland, Maine. The first daily report was issued 26 May.
The third office was opened in Chicago, Ill., in August, because it was the nation's largest inland market and distribution center for domestic and imported saltwater products and an important market for domestic and Canadian freshwater fish. The first daily report was issued 1 September.
The fourth office was opened in Seattle, Wash., also in August. Seattle was chosen because of its importance as a salmon, halibut, bottomfish, crab, and oyster landing, processing, and distribution center. The first report was issued 1 October. For a few years a suboffice was opened in Astoria, Oreg., but it was closed because of a shortage of funds.

1939
The fifth Fishery Market News Service office was opened in Jacksonville, Fla., in January. The office issued a report giving daily fishery landings for and shipments from the principal Florida ports and market data for New York City covering the species of Florida seafood shipped to that market for sale. The first daily report was issued 6 March.

1940
The sixth Fishery Market News office was opened in New Orleans, La., in January, and issued reports on the production, processing, and marketing of shrimp, oysters, and crabs in the entire Gulf area.

1942
Wholesale prices were collected in 1942 for the Office of Price Administration and used in preparing Maximum Price Regulations. From 1943 through the end of World War II, *Current Fishery Trade* was published monthly during periods of heavy production and quarterly the rest of the time.

1943
The Jacksonville office, opened in 1939, was closed in August owing to a cut in funds.

1945
The seventh Market News office opened in San Pedro, Calif., and the daily report, first issued 1 August, covered data on the tuna, mackerel, sardine, and anchovy fisheries.
The eighth Market News office was opened in Hampton, Va., covering the oyster and crab fisheries and the local trawl fishery. The first report was issued 4 September.
The Jacksonville, Fla., office, closed in August 1943, was reopened in January.

1947
On 1 July, the Hampton, Va., office was closed owing to a lack of funds.
Again the Jacksonville, Fla., office was closed in June owing to a cut in funds.

1948
Because of heavy industry interest, the Hampton, Va., office was reopened in July after a year's closure.

1954
Saltonstall-Kennedy Act gave increased funding to Market News in late 1950's. Programs were increased to cover foreign imports, cold storage, frozen prices.
The Boston frozen fish block and fillet prices are used worldwide and promote a stabilizing factor in international trading. The frozen shrimp and lobster tail prices published in New York reports have gained international standing. These frozen prices are published in other NMFS Market News Reports and reproduced in many international trade reports.
Many foreign governments use the prices, cold storage holdings and import data for economic evaluations relating to their fisheries and markets.

1957
The operations of the Hampton, Va., Market News Service Office were expanded to include Baltimore, Md., market coverage at the request of the industry. In September, a suboffice was established in Baltimore to report daily receipts and prices on the Baltimore market for publication in the Hampton daily report.

1958
"Boston Annual Summary" expanded to the "New England Fisheries Annual Summary."

1966
The *Commercial Fisheries Review*, a monthly periodical begun by Market News in 1939, was transferred to another office for publication.

1972
As of July, Monthly and Annual Summaries were discontinued—Market News was to provide current marketing information.

1973
Automatic telephone message centers were set up in Boston, Gloucester, and New Bedford, Mass.; New York City, Hampton, Va., and Chicago, Ill.
Hampton, Va., and Chicago, Ill., discontinued publishing Fishery Market News Reports on 5 March. Some of the information from Hampton and Baltimore was published in the New York Report. The Chicago information was put in the Boston Report.
Major changes were made in the coverage of the Market News Reports. Weekly summaries were discontinued. Fish meal and oil prices were not carried in all reports. Weekly cold storage reports were discontinued. However, industry strongly requested that Boston return to publishing the weekly cold storage report.

1975
Fishery Market News-Report began a paid subscription system on 1 July. Reports had been free from 1938 to 1975.
Weekly summaries were established as part of the Market News Reports.

1978
Telephone message centers at Gloucester and New Bedford, Mass., increased to two-line service to meet demand.
Commenced publishing "Fishing Export Opportunities" as a supplement to the Boston and New York Fishery Market News Reports on 1 October.

1979
Boston Market News office began providing Boston and New Bedford daily landings and morning auction prices to Western Union's FYI—News Alert on 5 March.
An automatic telephone center began 26 July at Gloucester, Mass., to report the Atlantic giant bluefin tuna catch figures during the summer months.
On 27 September a contract was issued to collect foreign export market information in five European countries.

1980
On 9 January, first issue of European Weekly Frozen Fish Report (distributed by telephone message center for the first four months—separate mailing list created as of 23 April).
Baltimore Market News office was closed 28 February.
Automatic telephone message center began 23 July at Portland, Maine.
Because coverage of the Baltimore Wholesale Fish Market was accorded a low priority, reporting for that market was suspended on 28 February. Prices and receipts for the Baltimore market had been appearing in the New York Market News Report.

1981
January, began the Japanese Weekly Frozen Fish Report, a 1 year project.
Commenced Quarterly European Frozen Fish Market.
11 February, commenced publishing the European Weekly Frozen Fish Report as a supplement to the Boston and New York Fishery Market News Reports.
Chicago Market News office was closed 1 October. Reductions forced a reassessment of program priorities. NMFS was to focus its development activities on marine species of fish and to de-emphasize freshwater species.

1983
Telephone message center at Boston was expanded to two-line service to meet demand.

1984
An automatic telephone message center was established 5 July in Rockland, Maine, providing the daily Boston landings and ex-vessel auction prices and New Bedford ex-vessel scallop auction prices.

2) Eliminate the merchandise trade and travel deficits by 1990.

3) Increase the number of exporters by 10 percent per year through 1985.

4) Provide accurate and timely information and services to U.S. exporters.

5) Produce economic forecasts and industry analyses that are useful to business and government.

6) Provide technological information, products, and services to meet the major long-term needs of U.S. industry.

7) Promote new commercial uses of marine resources by U.S. industry.

8) Increase by 40 percent the domestic fisheries contribution to GNP by 1990.

9) Manage Departmental services to minimize competition with the private sector and generate cost recovery from users.

Table 1.—Users of Market News Reports

User	How Data is Used	Data Needs
Private industry	Day-to-day business decisions by importer, brokers, processors, wholesalers, etc., throughout the marketing chain.	Landings, imports, exports, cold storage holdings, consumption, vessel, wholesale and retail price export trade leads, news items[1]
	Research and consulting firms	Same
	Newsletters/Market Reports	Same
	Media	
	Radio, land and marine	Landings and vessel prices
	Newspapers	Same
	Western Union	Auction and wholesale prices
NOAA/NMFS policy makers	Policy decisions, USDA purchase programs, special aid to industry	Catch, imports, stocks, exports, consumption prices
	Status of fisheries reports	Same
Fishery Management Councils	Fishery Management Plans Environmental Impact Statements Implementing regulations FMP amendments Joint Venture approvals/disapprovals	Landings, prices Special studies[2]
State fisheries agencies	Fishery management	Landings
Sea Grant universities	Biological studies Economic studies	Landings Supplies, prices, consumption

[1]For example: Management Council agendas and reports of meetings, convention and trade show announcements, availability of reports on foreign fisheries, opening and closing of seasons by states, *Federal Register* announcements, announcements by other agencies such as USDS, FDA, ITC, Interior, etc.
[2]A wide variety of studies are used in the preparation of FMP's. Market News provides data for many of the studies, particularly economic and industry studies.

Who Uses the Market News Reports?

Current fishery market data are of great importance to many businessmen as well as to fishermen, producers, and vessel owners. Sales departments of hundreds of firms can use the data to help forecast sales. Bankers use them in determining how their loans are performing, financing inventories of fish, and providing new plants and facilities. Since the data aid businesses in avoiding loss and in utilizing their facilities most efficiently, they doubtless serve the consumer through the lower costs which result from such knowledge.

Price trends tell the businessman, researcher, and Government official something about the future, provided they have data on prices regularly and they learn how to interpret them. Price trends follow demand and do show what the demand is for any particular product. Is the demand starting to decline? Is it holding steady? Is it beginning to increase? The answers to those questions are found in the information on price trends and other market data.

Market News plays an important part in facilitating international trade in fishery products. An example of how Market News comes into play is as follows. Suppose a U.S. shrimp importer wishes to contract with a supplier of shrimp in another country. The contract may be for 3-12 months, or even longer. The problem is how can a contract be written now to specify exact prices to be paid for the shrimp months from now when everyone knows of the day-to-day volatility in shrimp prices. To get around this problem, the buyer and seller must agree on an independent source of data. It must be a source where prices cannot be determined or influenced by either the buyer or seller, and it must reflect current market conditions. All around the world, forward contracts for shrimp are based on the the New York Market News Greensheet. Contracts will be written for prices being based on the published prices for a certain size of shrimp from a particular country at a given date. This means the U.S. and the international industry has confidence in the integrity, and the objectivity, and the thorough reporting of the Market News Service. Lobster tails are traded in much the same manner. The Boston Market News Bluesheet is used for forward contracts for fish blocks and fillets.

Users of Market News data and information can be classified into two broad groups: 1) Private industry and 2) Federal and state government officials. The latter, in turn are primarily concerned with both the development of the industry and the management of fishery stocks. Who uses the data and how it is used are briefly summarized in Table 1.

What Do the Market Reports Accomplish?

A progressive fisherman, producer, vessel owner, processor, wholesaler, or importer uses the reports for many purposes. Perhaps the most important is for information on the seasonal aspects of the market for a specific type of seafood product. A vessel owner is able to determine whether it may be more desirable to fish for the fresh fish market or for the processors of frozen fish.

The reports can give an indication as to whether fishing in a particular area is beginning to drop below nor-

mal. This aids in deciding whether a shift to different grounds is warranted without a costly trip.

Not the least of the purposes is to keep all those in the industry chain generally informed on the overall condition of the fishery industry and market, thus making each individual in the industry a more intelligent businessman.

The reports are especially valuable when the industry is in trouble, for the recorded current information is invaluable to those who have to make plans and devise policies at the Federal and state levels on how to help the industry. The data also may show why the sector is in trouble.

Full disclosure of market conditions, landings, receipts, and prices is needed to preserve a climate of fair dealing. This is also essential to maintain investor confidence in the fishing industry. Market information concentrates the buying power of the market in the proper channels and avoids disruptions of prices and demand based on rumors. It stimulates active and unrestricted bidding based on accurate data. This exerts a stabilizing influence on the market to the benefit of both buyer and seller, the latter securing as high a price as market conditions warrant. This also results in fair returns on consignment shipments.

One important by-product of the exchange of market information is that it generally leads to increased knowledge of trading opportunities and eventually to increased trade. A buyer or seller never knows when a bit of market information might spark a new sale or outlet for a product.

The current publication and availability of prices serves as a guide for private transactions. The dissemination of prices to all segments of the fishery industry provides for a certain amount of stability. There are narrower fluctuations with proper and current market information because buyers and sellers can handle large or small supplies better if they have some advance notice. If sharp fluctuations can be reduced to only moderate or small fluctuations, the entire fishing industry will be operating under more stable conditions. Some of the guesswork will have been removed.

How Market News Differs From Other Reports

When you look at the variety of information published in Market News reports, and for much of it Market News is the sole vehicle of publication, the reports could easily be considered as the seafood industry's daily newspaper, its "eyes and ears." NMFS Regional Directors use the reports as a primary means of communicating their regional activities. The Fishery Management Councils and the Fisheries Development Foundations make use of the reports to report on their activities. *Federal Register* announcements are usually run giving the industry access to the relatively unknown *Federal Register*. States use the reports to announce openings and closings of fishing seasons. Export opportunities are regularly published. The availability of reports on foreign fishing activities is routinely announced. Items such as these would not fit into the regular statistical publications and the official scientific publications of the Agency. Thus Market News is the natural medium to get widespread distribution quickly to the industry within 2-3 days.

Limitations

Market News reporting has limitations peculiar to the various products covered. Extent of coverage is also guided by marketing practices which differ among products. For example, New York reporters must maintain the simplest records feasible because of the large number of species reported and because they interview many individuals handling numerous products. Time limitations, commodities covered, and the needs of the industry determine the degree of detailed information reported.

Most Fishery Market News Reports indicate at what level trading has taken place for different sizes, qualities, and other factors that affect prices. Reporters usually cannot obtain weighted average prices for all pertinent transactions. Available time and manpower limit the extent to which complete coverage can be attained on many products. However, within these limitations, judgment is exercised so reporters weight prices on the basis of reported or observed volume of sales at the different prices.

When Market News Reports are used for supporting claims for statistical purposes, the general practice is to use the midpoint of the price range. Such a derived figure may or may not be an accurate estimate of the true weighted average price, although in many instances it is acceptable as the best available approximation.

The value of the Market News Service is seriously limited in any case where only a small amount of production or sales is reported. When this happens, the Market News Service must (and frequently does) indicate that there were not enough quotes to establish a market price.

Other limitations include: Lack of trading in some items with the result that they are not quoted consistently; distress sales; a tendency of some sellers to quote asking prices instead of actual selling prices; and special trades for quick delivery priced outside the normal market range. The reports generally do not include prices on all grades and sizes, advertising allowances, but confine coverage to those most widely traded; shrimp wholesale prices are a good example.

Future of Market News

This report has traced briefly the major developments in the Market News Service over five decades. It has shown that the original concept of supplying market data for the industry has expanded significantly. Now, Federal and State Governments make wide use of the data as do the Regional Fishery Management Councils and Fishery Development Foundations. Market News is just as necessary to Government as it is to private industry because it supplies much data that are available from no other source, and it is the quickest mode of supplying any fisheries data.

The modes of supplying data are

the area where we foresee the most changes in Market News in the future. The use of computers will bring drastic changes to Market News operations, and possibly its printed looks, for the remainder of the 1980's. By the early months of 1985, each Market News office had its own microcomputer. The word processing capabilities of these machines and their capability to transfer data from office to office has reduced typing to a minimum. Computers will enable changes in formats and the way data and information are presented.

For the first time, the price data collected by Market News—and used by a wide range of researchers—will be transferred regularly to an automated data base. This will allow users instant access to the latest prices and historical price trends. The first use of data transfer has been with the exchange of export trade leads. All leads are being put into a central computer file. Each Market News office is able to access the leads and publish them on a more timely basis than in the past.

The greatest potential for dollar savings and the greatest potential for program efficiencies lie in the delivery of market news. An expensive and relatively less efficient form of dissemination is the mailed report. Mailed reports can become financially burdensome.

The use of telephone answering devices for disseminating market news information has grown over the last decade. Devices are located primarily at eight ports in the Northeast area. Hundreds of calls are received daily from small businesses and others that would have to depend upon a slower means of dissemination. In addition, the devices are used to record market news information by radio stations for broadcast.

If electronic trading shows promise as it has with agricultural products, this can serve as a source of market news.

The industry can no longer depend on the mailed report for daily marketing decisions. The fast pace in trading and sharp fluctuations in prices for most commodities require more up-to-date market information than can be provided by the mailed market news report. The movement away from mailed reports to more rapid and efficient means of market news dissemination is the wave of the future.

Conclusions

The majority of the seafood industry and others using current fishery data realize the value of having current, unbiased, and continuing information on fishery landings, stocks, prices, market conditions, and trends.

As the industry becomes more sophisticated, as more and more products are processed, and as the trade in those products becomes larger and more national and international in character, the need for unbiased market information on a current basis will be essential for the orderly marketing of all types of fishery products. The proper information, at the proper place, and at the proper time aids the movement of a greater variety and larger quantities of fishery products. Without adequate and current market data, the efficient marketing and smooth flow of fishery products from production to consumption will be handicapped. The market reporting system does not change the marketing structure—it merely reports market conditions as generated by the existing marketing structure.

The seafood industry is becoming more sophisticated. Before any buyer or seller, any investor, any banker, any government official, or any other individual in the industry can make a profitable and wise decision, he will need detailed and timely information about prices, market conditions, demand, and other factors which affect the marketing of fishery products and by-products. General information will no longer be sufficient, but he will need specific data which will be helpful in arriving at a sound and businesslike decision.

Under today's complex marketing conditions, lack of or inadequate market and price information hampers businessmen and government officials from making proper and accurate day-to-day decisions or planning far enough ahead. This adversely affects the orderly marketing of products.

Current market information is effective and useful when it tells the businessman and government official the score on the fishing industry. Sometimes market difficulties can be avoided if the small as well as the large marketer or businessman has the information necessary to make the proper market decision.

Acknowledgment

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California Anglers Reap Largest Albacore Catch

Record numbers of albacore were reported caught in 1984 by southern California sportfishermen. Sportboats began making catches in late May off northern Baja California and shifted to off southern California in June, and excellent angling continued throughout the summer.

San Diego landings often exceeded 6,000 fish per day, with angler success sometimes exceeding more than 10 albacore per rod. In addition to the large catch, several albacore world line class records were broken late in the season. An unusually high number of 60- to 80-pound albacore were caught in 1984 inside the Channel Islands, notably about 10 miles off San Pedro.

NMFS Southwest Fisheries Center scientists believe that the large fish were part of a group of albacore that winter over near Guadalupe Island off southern Baja California. It appears, however, that the fish moved northward in 1984 in response to the lingering El Niño condition and were held near the coast in the Los Angeles Bight by ocean frontal conditions just outside the Channel Islands. (Source: Tuna Newsletter No. 83.)

Destruction of Coral and Coral Reefs Prohibited

The taking of coral in the Gulf of Mexico and South Atlantic is prohibited, reports Jack T. Brawner, National Marine Fisheries Service's Southeast Regional Director. Federal regulations, which implement the Fishery Management Plan for Coral and Coral Reefs, now protect over 400 species of coral and apply to the fishery conservation zone which extends from the outer boundary of state waters (9 n.mi. off Texas and the west coast of Florida, and 3 n.mi. off the east coast of Florida and the other states) seaward to a distance of 200 n.mi. from the coastline.

Protected corals include fire corals, hydrocorals, sea fans, sea whips, precious corals, sea pens, and stony corals, as well as hard bottoms, deepwater banks, patch reefs, and outer bank reefs. Taking of coral is defined to include damaging, harming, or killing of the coral.

According to Brawner, there had been substantiated reports of wholesale destruction of coral reefs before the regulations went into effect. "Destruction of our coral reefs cannot be tolerated," said Brawner, adding "Harvesting corals must be for scientific or educational purposes." Corals are live but sedentary organisms, particularly vulnerable to physical and biological destruction. Because many species are slow growing, they would not recover for many years if damaged.

The regulations also establish habitat areas of particular concern for corals that are currently or potentially threatened. These areas include the West and East Flower Garden Banks off Texas, the Florida Middle Grounds off the west coast of Florida, and the Oculina Bank off Ft. Pierce, Fla. Fishing with longlines, fish traps or pots, and bottom trawls in these threatened areas is prohibited. Any illegal taking of coral in the fishery conservation zone should be reported to Federal law enforcement officials. Violators may face penalties up to $25,000 for each offense. Anyone taking corals must have a permit from the National Marine Fisheries Service. Information on permits and current regulations may be obtained from the Fishery Operations Branch, National Marine Fisheries Service, 9450 Koger Boulevard, St. Petersburg, FL 33702, (813) 893-3723.

Foreign Fishery Developments

New Peruvian Plant to Produce "Marine Beef"

A Japanese engineering company has built a "marine beef" plant in Peru which will produce a dehydrated protein concentrate that reportedly can be used in a variety of meat and poultry dishes. The pilot plant, for Peru's state-owned fishing company, Pescaperu, is located at the largely unused San Andres Fisheries Complex near Pisco, about 230 km south of Lima.

Marine beef is a new type of fish protein concentrate which can easily be rehydrated for home use. Its unique feature is that it reportedly has the texture of ground meat when prepared and can thus be used in a wide variety of foods. Construction of the plant was completed in 1984, but the plant had not yet begun operating.

The process consumes large quantities of ethanol alcohol which is very expensive in Peru. About 97 percent of the alcohol is recovered, but the 3 percent consumed still increases the cost of the final product to the point that it cannot yet be successfully marketed in Peru. Pescaperu officials hoped to begin production at the plant in early 1985.

Peru has only a small livestock and poultry industry. Feed grains have to be imported, making it costly to raise both livestock and poultry in Peru. As a result, fish is the only inexpensive animal protein available to feed the country's rapidly growing population. There is a great demand, however, for meat and poultry. Pescaperu officials decided that the marine beef technology would be a way of converting the country's abundant fishery resources to a product that can be used in various meat and poultry dishes.

Home Preparation

Marine beef is a product that the average Peruvian consumer may find convenient and easy to use. It has a faint smell of alcohol and fish, but this disappears when the product is soaked in water before cooking. The consumer can easily rehydrate marine beef by soaking it in water for about 40 minutes. After rehydration it is rinsed in water a few times and then is ready to use. Marine beef expands to about 5 times its dry weight. It is flavorless and can be used either as a meat "extender" or by itself, usually in food that has sauces to provide the flavor. Bouillon can also be used to flavor it. Pescaperu officials report that the product has been tested in Lima restaurants and that no one detected the substitution of marine beef for the meat or poultry dish ordered.

Raw Material

Marine beef can be made from

either pelagic or demersal fishes, and the end product has virtually identical characteristics, regardless of the species used. This was an important factor for Peru, because many of the alternative fishery products, such as minced fish and surimi, are currently made mostly from demersal species with a low fat content. The marine beef can be made from the more oily pelagic species found off Peru. Pescaperu planned to begin production with sardines, but other species, (i.e., jack mackerel) which exist in even larger quantities off Peru, can also be used.

Processing

The Pisco pilot plant's capacity is about 1 metric ton (t) of marine beef in 12 hours. Depending on the condition of the fish, it takes from 16 to 22 t of raw fish to produce 1 t of marine beef, giving yields of 4.5-6.2 percent. The lower yield was obtained from fish in poor condition with which Pescaperu was experimenting to determine in what condition fish can be fed into the process. This is an important factor, as Peruvian fishermen are accustomed to catching fish for reduction to fishmeal, and many vessels are not equipped to handle fish which will be used to produce edible products.

Marine beef is made by concentrating fish protein without altering the amino acid balance. The fish is run through the plant on a continuous line. The heading, skinning, deboning, and mincing steps are the same as in other fish processing procedures. The bones and offal are used to make fishmeal. The minced fish is washed with water to remove refuse and blood. The water is then removed by a screw process. Most of the process is run at low temperatures to prevent protein destruction.

The meat is next put through an alkali blanching process by adding sodium bicarbonate. Additives are mixed, the pH adjusted, and the product kneaded. Kneading the fish with salt breaks down the muscle fiber and forms a viscous paste which is mixed with the alcohol to denature and coagulate the protein, precipitating the muscle fibers into a new fiber structure similar to meat. The product is then extruded and put through four solvent extraction steps to remove as much of the fat as possible. The product is finally dried and packaged as pellets. Dust from the pelletization process will be collected for use as high-protein additives in other foods. The alcohol extracted from the process is purified and reused. Fish fat from the washing and alcohol purification is recovered and refined to produce fish oil.

Composition

The final product is about 90 percent protein. The primary amino acids are lysine and leucine, but six other amino acids are found in significant quantities (Table 1). The product is virtually fat-free and has a moisture content of less than 8 percent.

It is claimed that the low-fat, low-calorie, but high-protein product is a healthy food. It has a protein content similar to beef and pork, but with fewer calories. Japan's National Nutrition Institute has approved the use of marine beef for human consumption. No artificial substances or harmful additives are used. The major substances added are salt and sodium bicarbonate. The ethanol alcohol, used to sterilize the product and to remove the fat, also has the added benefit of removing cholesterol, polychlorinated biphenyls (PCBs), and agricultural chemicals which may be present in the fish.

Marketing Plans

Peruvian officials plan to market marine beef in several different ways. The goal is to first refine the process and reduce the price of the end product to less than half of the price for ground beef. The product could be used in the "Restaurantes Populares" subsidized by the Government for low-income consumers. Trials with spaghetti and marine beef "meat sauce" at these restaurants, for example, have been successful. Officials also plan to use marine beef for school lunches and in preparing food for the military. It will be sold in food stores, both by itself and mixed with ground beef and pork. Other products such as paste and cookies with marine beef added are also being studied.

Marine beef is also expected to be an attractive product to market in isolated Andean villages. The virtual absence of fat enables it to be shipped and stored without refrigeration. Marine beef can be stored at room temperature for up to 2 years. The new product has an added marketing advantage in that it is a dehydrated product which substantially reduces transportation costs. These advantages will make it possible for marine beef to be marketed in Peruvian towns and villages that do not normally receive seafood shipments.

Marine beef may also have export potential. It could be a convenient food for campers and hikers, given its light weight and storage characteristics. The growing popularity of outdoor activities in the United States and other countries could represent a ready market. (Source: IFR-84/65R.)

Table 1.—Marine beef technical data for final dry product, based on marine beef from Alaska pollock produced in Japan.

Composition		Proteins	
Item	Percent	Amino acid	Percent
Protein	88.0-92.0	Lysine	9.75
Moisture	6.3-7.6	Leucine	7.35
Ash	2.0-4.4	Threonine	4.19
Fat	Negl.	Valine	4.12
		Isoleucine	3.70
		Phenylalanine	3.14
		Methionine	3.04
		Tryptophan	1.20

Peru Harvests and Cultures Scallops

Peru has developed an important new fishery for the scallops *Argopecten purpuratus*. While scallops have always been present off Peru, until the 1982-83 El Niño event, they were never harvested in commercial quantities. Peruvian biologists are divided as to whether the population increased as a result of El Niño or whether large populations were

always there, but not utilized. As a result, Peruvian officials do not yet know whether the return of more normal oceanographic conditions along the Peruvian coast will affect the scallop population. Most of the production is currently shipped frozen to the United States. These shipments totaled almost 930 metric tons (t) worth $6.6 million in 1983 (Table 1). There were no shipments in 1982. Smaller quantities are shipped to Europe, mostly France. Exports to the United States began to decline in April 1984, primarily because of a closed season in the major fishing area.

Peru's scallop catch is currently taken by divers. Several fishermen, however, have obtained Government concessions from the Ministry of Fisheries to culture scallops in coastal areas. The concessions range in area from 0.5 to 10.0 hectares. One of the centers of this activity is an area near Pisco, about 230 km south of Lima. Scallop fishermen first began to stock concessions with juvenile scallops in mid-1983. The participating fishermen have just began to harvest the seeded scallops. Data on the results of these harvests are not yet available, but preliminary reports suggest profitable returns.

Collecting Juveniles

The scallops are gathered by divers from boats 10-15 m in length. The boats generally have air compressors which pump air to the divers so they do not have to surface continuously. Most of the boats are based at Chaco or at the San Andres Fisheries Terminal. The diving is usually conducted from 8:00 a.m. to 1:00 p.m. The divers use a "capacho" net to collect the scallops. Those that are under 5 cm are used to seed new scallop beds. The seed scallops are sold for about $4.00 for a can containing about 960 juveniles. Scallops are sold in sacks containing 8 dozen (96) scallops which are called a "manojo." The smaller seed oysters are sold in cans containing about 10 manojos. Divers report that they can collect from 6 to 30 cans of scallops per day.

Table 1.—Peruvian scallop exports to the United States, 1983-84.

	Exports (1,000 t)	
Month	1983	1984
January		245.1
February		246.8
March		248.5
April		[1]100.2
May		[1]76.5
June		[1]101.6
July		[1]16.8
August	6.9	
September	66.3	
October	179.9	
November	257.2	
December	417.9	
Total	928.1	

[1]Closed season imposed in major fishing areas.

Stocking Juveniles

Divers disperse the juvenile scallops in the Government concessions obtained by the fishermen. The area chosen for the concessions is shallow coastal water, 2-5 m deep. Stocking density varies, depending on the availability of juveniles and individual practices of each fishermen. As scallop culture is a new activity in Peru, data to establish optimal stocking densities have not yet been collected and analyzed. One company began to seed a 1.3 hectare concession on 26 March 1984, and has seeded a total of 173,000 juveniles. Its scientific advisor, Rene Mayo, believes that about 100 scallops/m^2 can be stocked (about 1 million scallops per hectare), but others say this is much too dense. The company is collecting data on salinity, dissolved oxygen, and temperature, and every week a diver checks the scallops, looking especially at mortalities. They report mortalities totaling only about 2 percent. The biggest problem appears to be predators like sea snails, octopus, and crabs. Divers periodically clear such predators from the concessions. Human poachers are another problem, and growers now arm guards who remain on rafts during the night with shotguns.

Hatchery Seed

Researchers at the Fisheries School of the Universidad Agronoma "Molina" (UAM) in Lima have been producing juvenile scallops in a hatchery. UAM researcher Victor Venturi H. reports success in raising juveniles using "berried females." UAM does not currently plan to breed scallops as it believes an adequate supply of juveniles can be produced using the "berried females." Closing the breeding cycle is a much more difficult task, which would require more funding than is currently available. (Source: IFR-84/68.)

Chilean Fishing Harvest Reported

Chile reported a record catch surpassing 4.0 million metric tons (t) in 1983, up 8 percent over 1982. The 1982-83 "El Niño" phenomenon increased the quantity of the landings, apparently causing a shift southward into northern Chilean waters of fish normally found further north off Peru. The El Niño also affected the species composition of the catch. The two major fish species caught, however, remained the South Pacific sardine (2.8 million t) and the jack mackerel (0.8 million t). These pelagic fishes are the backbone of the fishmeal industry.

Fishmeal production and exports constituted, as before, the single most important activity of the industry. Clams made up the greatest percentage of mollusks, and crabs were the leading crustaceans. *Gracillaria* sp. was the leading seaweed. Fishmeal production utilized over 85 percent of all marine landings by quantity. The value of exports reached $445 million, 8 percent above the 1982 level, accounting for nearly 12 percent of total Chilean export earnings.

The U.S. Embassy in Santiago has prepared a 21-page report on Chilean developments. The report includes information on resources, landings, utilization, exports, companies, employment, fleet, and aquaculture. Interested U.S. companies can purchase a copy for $7.00 by ordering report number PB85-134450 from NTIS, Springfield, VA 22161. (Source: IFR-84/102.)

New NMFS Scientific Reports Published

Some publications listed below may be sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Copies of all are sold by the National Technical Information Service, Springfield, VA 22151. Writing to either agency prior to ordering is advisable to determine availability and price (prices may change and prepayment is required).

NOAA Technical Report NMFS 14. Dadswell, Michael J., Bruce D. Taubert, Thomas S. Squiers, Donald Marchette, and Jack Buckley. **"Synopsis of biological data on shortnose sturgeon, *Acipenser brevirostrum* LeSueur 1818."** October 1984, iv + 45 p., 43 figs., 24 tables.

ABSTRACT

Information on the biology and populations of the shortnose sturgeon, *Acipenser brevirostrum*, is compiled, reviewed, and analyzed in the FAO species synopsis style. New information indicates this species exhibits biological and life-cycle differences over its north-south latitudinal range and that it is more abundant than previously thought.

NOAA Technical Report NMFS 15. Michel, Harding B. **"Chaetognatha of the Caribbean Sea and adjacent areas."** October 1984, iv + 33 p., 41 figs., 5 tables.

ABSTRACT

This illustrated manual is a guide to the distribution and identification of the 6 genera and 28 species of benthic and planktonic Chaetognatha known to occur in the Caribbean Sea, the Gulf of Mexico, the Florida Straits, and the southwestern North Atlantic Ocean. As background, previous studies of chaetognaths in these areas are reviewed, gross morphology of the different forms is described, and instructions on methods of preserving and handling specimens preparatory to identification are provided. The key to genera and species is preceeded by a discussion of chaetognath taxonomy. A description of each species, consisting of an abbreviated synonymy, a summary of taxonomically important morphological features, and horizontal and vertical distribution follows the key. The occurrence of species in relation to water masses in the Caribbean and adjacent areas is noted.

NOAA Technical Report NMFS 16. Sindermann, Carl J. (editor). **"Proceedings of the Ninth and Tenth U.S.-Japan Meetings on Aquaculture."** November 1984, 92 p. (11 papers.)

NOAA Technical Report NMFS 17. Wolff, Gary A. **"Identification and estimation of size from the beaks of 18 species of cephalopods from the Pacific Ocean."** November 1984, iv + 50 p., 55 figs., 3 tables.

ABSTRACT

A method of identifying the beaks and estimating body weight and mantle length of 18 species of cephalopods from the Pacific Ocean is presented. Twenty specimens were selected from each of the following cephalopod species: *Symplectoteuthis oualaniensis, Dosidicus gigas, Ommastrephes bartramii, S. luminosa, Todarodes pacificus, Nototodarus hawaiiensis, Ornithoteuthis volatilis, Hyaloteuthis pelagica, Onychoteuthis banksii, Pterygioteuthis giardi, Abraliopsis affinis, A. felis, Liocranchia reinhardti, Leachia danae, Histioteuthis heteropsis, H. dofleini, Gonatus onyx,* and *Loligo opalescens*. Dimensions measured on the upper and lower beak are converted to ratios and compared individually among the species using an analysis of variance procedure with Tukey's omega and Duncan's multiple range tests. Significant differences ($P = 0.05$) observed among the species' beak ratio means and structural characteristics are used to construct artificial keys for the upper and lower beaks of the 18 species. Upper and lower beak dimensions are used as independent variables in a linear regression model with mantle length and body weight (log transformed).

NOAA Technical Report NMFS 18. Wenner, E. L., P. Hinde, D. M. Knott, and R. F. Van Dolah. **"A temporal and spatial study of invertebrate communities associated with hard-bottom habitats in the South Atlantic Bight."** November 1984, iii + 104 p., 6 figs., 8 tables, 3 app.

ABSTRACT

Species composition, biomass, density, and diversity of benthic invertebrates from six hard-bottom areas were evaluated. Seasonal collections using a dredge, trawl, and suction and grab samplers yielded 432,525, and 845 taxa, respectively. Based on collections with the different gear types, species composition of invertebrates was found to change bathymetrically. Inner- and middle-shelf sites were more similar to each other in terms of invertebrate species composition than they were to outer-shelf sites, regardless of season. Sites on the inner and outer shelf were grouped according to latitude; however, results suggest that depth is apparently a more important determinant of invertebrate species composition than either season or latitude. Sponges generally dominated dredge and trawl collections in terms of biomass. Generally, cnidarians, bryozoans, and sponges dominated at sites in terms of number of taxa collected.

The most abundant smaller macrofauna collected in suction and grab samples were polychaetes, amphipods, and mollusks. Densities of the numerically dominant species changed both seasonally and bathymetrically, with very few of these species restricted to a specific bathymetric zone.

The high diversity of invertebrates from hard-bottom sites is attributed to the large number of rare species. No consistent seasonal changes in diversity or number of species were noted for individual stations or depth zones. In addition, H' and its components showed no definite patterns related to depth or latitude. However, more species were collected at middle-shelf sites than at inner- or outer-shelf sites, which may be related to more stable bottom temperature or greater habitat complexity in that area.

NOAA Technical Report NMFS 19. Darcy, George H. **"Synopsis of biological data on the spottail pinfish, *Diplodus holbrooki* (Pisces:**

Sparidae)." January 1985, iv + 11 p., 8 figs.

ABSTRACT

Information on the biology and fishery resources of the spottail pinfish, *Diplodus holbrooki*, is compiled, reviewed, and analyzed in the FAO species synopsis style.

Fish and Fisheries in Contaminated Water

Publication of **"Contaminant Effects on Fisheries,"** edited by Victor W. Cairns, Peter V. Hodson, and Jerome O. Nriagu, has been announced by John Wiley & Sons, Inc., 605 Third Avenue, New York, NY 10158, as Volume 16 in the Wiley Series in Advances in Environmental Science and Technology. In it, a number of leading toxicologists and fisheries biologists from Canada and the United States review and examine the bioaccumulation, metabolism, and excretion of toxicants by fish, the effects of those toxicants on certain fisheries, and recommend additional studies.

The book addresses the tolerance of fish and fish populations to the stress of environmental alterations, and covers the changes in the biochemical and physiological systems associated with exposure to common toxicants. Epidemiology of fish diseases induced by toxicants is reviewed, and strategies for reestablishing disturbed fisheries are outlined.

Portions of the book are derived from a Great Lakes Fishery Commission workshop which was convened to discuss suitable methods for assessing the effects of contaminants on wild fish populations. The first two chapters provide a background to Great Lakes chemical and fisheries problems and introduce the basic concepts of epidemiology.

Other chapter topics include epidemiology of diseases in wild fish populations, a critique of the use of histopathology in aquatic toxicology, biochemical indicators of stress in fishes, fish serum chemistry as a pathology tool, using physiological tests to measure fish health, monitoring lead exposure of fish, a review of metallothionein and fish acclimation to heavy metals, the adenylate energy charge as a measure of stress in fish, problems and methods of monitoring fish tolerance to environmental stress, modeling approaches for assessing the effects of stress on fish populations, and more. Thus, it provides a comprehensive review on the impacts of water pollutants on fishes and fish culture. The 333-page hardbound volume is available from the publisher for $69.95.

Marine, Freshwater Research Methods

The second edition of IBP Handbook 16, **"Methods for the Study of Marine Benthos,"** edited by N. A. Holme and A. D. McIntyre, has been published by Blackwell Scientific Publications, Inc., The Downing House, 706 Cowper Street, Palo Alto, CA 94301. The handbook deals primarily with the sampling and study of sediments and their biota from the intertidal zone to the deep sea, and reflects much of the changing needs and directions of such studies in the 12 years since the original edition was published; many of the contributions have been considerably revised or completely rewritten.

Included are chapters discussing the design of sampling programs, position fixing of ship and gear, sediment analysis, photography and television, diving, macrofauna techniques, meiofauna techniques, phytobenthos sampling and estimation of primary production, and energy flow measurements. Each chapter also includes many references necessary to provide precise details on the various techniques and studies. Thus, the volume is a good general guide to the equipment and techniques used in studying marine benthos. Indexed, the 387-page hardbound volume is available from the publisher for $44.00.

Publications of **"Methods in Marine Zooplankton Ecology,"** by Makoto Omori and Tsutomu Ikeda, has been announced by John Wiley & Sons, Inc., 605 Third Avenue, New York, NY 10158. Omori is with the Tokyo University of Fisheries and Ikeda is with the Antarctic Division of Australia's Department of Science and Technology. This is a basic book encompassing the principles, procedures, research problems, and current methods used in the study of marine zooplankton, and is a revision (based on a translation) of the authors' previous book "Methods in Zooplankton Ecology," published by Kyoritsu Shuppan, Tokyo, in Japanese in 1976.

The authors begin with a definition and ecological classification of zooplankton, then review and describe sampling methods, sample fixation and preservation, zooplankton observation and identification, processing and measurements, rearing and culture, feeding; measuring respiration, excretion, and productivity; and distributional patterns and community structure. Thus, the volume provides a sound, basic introduction to zooplankton and a review of field sampling strategies and laboratory methods for students and biologists. Indexed, the 332-page volume is available from the publisher for $44.95.

"A Manual on Methods for the Assessement of Secondary Productivity in Fresh Waters," Second Edition, edited by John A. Downing and Frank H. Rigler, has been published by Blackwell Scientific Publications, Inc., The Downing House, 706 Cowper Street, Palo Alto, CA 94301. The handbook is a good summarization of current literature and synthesis of recent technical progress, and deals with such topics as methods for estimating zooplankton abundance, sampling stream and standing water benthos, sampling aquatic insect emergence, estimating abundance and biomass of zooplankton in samples, statistical methods for experiment design and sample analysis, methods of studying zooplankton feeding, filtering, and assimilation, and respiration measurement. With author, taxonomic, and subject in-

dexes, the 501-page hardbound volume is available from the publisher for $55.00.

Charting and Navigation for Commercial Fishermen

Four handbooks of interest to marine vessel operators have been published by the Cornell Maritime Press (CMP), P.O. Box 456, Centreville, MD 21617. The first, **"Chartwork and Marine Navigation for Fishermen and Boat Owners"** by Geoff A. Motte with Thomas M. Stout, is an updating of two earlier URI Sea Grant manuals for fishermen. Part I, provides an introduction to chartwork, basic definitions for fixing position near land, reading a chart (symbols and abbreviations), general chart layout and construction, distance, the running fix, magnetism of earth and vessel, the compass and its use, chart projections, practical chartwork, the marine sextant, etc., providing readers with clear and concise step-by-step instructions in small-boat navigation skills.

Part II, Section 1, Marine Navigation, presents basic principles (data on the solar system, earth motion, moon motion, the stars, and instruments and sextant angles), while Section 2, Practical Navigation, gives data on azimuth and amplitude, latitude by meridian altitude, the Pole Star, celestial position line, three methods of sight reduction, fixing position, etc. In sum, the authors have presented a handy, well-illustrated reference to nautical astronomy and the primary approaches to sight reduction. In addition, hyperbolic grid concept and the Loran C system is explained, and practical exercises included are aimed at the conditions and situations likely to be encountered by fishermen and small-boat operators. Paperbound, the 173-page volume is available from the publisher for $11.50.

"Concise Tables for Sight Reduction", by Thomas D. Davies, is the third navigational table that the author, a retired rear admiral, USN, has developed. Earlier ones were "Star Sight Reduction Tables" and the "Sight Reduction Tables for Sun, Moon, and Planets" in which he introduced his "assumed latitude method of celestial navigation." In this new handbook, complete sight reduction is accomplished by the manipulation of six angles extracted from a very small set of tables (30 pages), with an accuracy superior to most other tables. Calculations are simple and speedy and present a simple method for eliminating errors from the use of an assumed position. The volume also contains a "Long Term Almanac" by which one can reduce star or sun sights when the current "Almanac" is not available. The 64-page paperbound volume costs $8.50.

"Celestial Navigation Planning" by Leonard Gray is a complete guide to precruise planning intended to save time at sea and improve navigation results that would be useful under less than optimum, or even survival, conditions. A basic knowledge of celestial navigation is assumed and, through detailed and worked-out examples, instructions, and illustrations, the author provides formulas for storm avoidance maneuvers, average boat speed, backup sight reduction, noon-sight computation, and a celestial navigation program for a programmable calculator.

Topics covered include planning the best departure dates and routes; a format for daily navigation guides for twilight sights, sun-and-moon fixes during the day and sights during the night, weather advice, planning for error reduction and landfall, etc. While the examples deal with a sailing cruise, elements of the system can also be used by recreational and commercial fishing vessels. Appendixes include necessary formulas, suggested publications, a glossary, excerpts from *Nautical Almanac* and H.O. 249, Vol. 1, a comparison of sight-reduction methods, and a sight-reduction form for H.O. 249 or H.O. 229, and more. The handy, indexed 133-page paperbound volume is available from the publisher for $12.95.

The new **"Yachting Signal Book"** by J. R. Collier, Capt., USN (Ret.), provides a universal code of signals primarily for recreational boaters, but with its emphasis on encoding and decoding flags and radio signals to relay messages between vessels, has broader interest, too.

Following a lengthy chapter on definitions and instructions is a second on emergency signals and signalling. Other chapters detail one- and two-letter signals, flag and pennant meanings, and flag use and etiquette. The author also provides an encoding directory, important extracts from the International Code of Signals, a color guide to special and international flag and pennant meanings, plus an encoding directory, and important extracts from the International Code of Signals. The 118-page hardbound volume is sold by the publisher for $17.50. In addition, a catalog of CMP and Tidewater Publishers titles on navigation, fishing vessels, oceanography, safety, conservation, and related maritime titles is available.

Canada's Atlantic Coast Fisheries and Management

Publication of **"Atlantic Fisheries and Coastal Communities: Fisheries Decision-Making Case Studies,"** edited by Cynthia Lamson and Arthur J. Hanson, has been announced by Dalhousie Ocean Studies Programme, 1321 Edward Street, Halifax, Nova Scotia, Canada. In short, this series of case studies relates the story of Canada's relatively recent Atlantic fishing industry expansion and contraction and the effects it has had on local communities, and the authors' attempt to draw several conclusions from them. It provides a perspective on fisheries management and community response to increased government intervention and regulation. Case studies related include management of Canada's offshore groundfisheries, bluefin tuna, Bay of Fundy herring fisheries, Newfound-

land inshore fishery, small boat fishery of Southwest Nova Scotia, and the consolidation of corporate power in the Nova Scotia fish processing industry.

The authors use those cases to explore the many complexities involved in fisheries decision making in Canada's Atlantic fisheries sector, and the effects of those decisions on the fishermen, communities, and processors. They also discuss the processes involved in making fisheries decisions and the perceived need to involve fishermen and communities more in helping make those decisions. The paperbound volume is available from The Institute for Resource and Environmental Studies, 1312 Robie Street, Halifax, Nova Scotia, Canada, B3H 3E2 for $18.50.

Biology and Culture of Red Swamp Crawfish

An updated edition of **"Red Swamp Crawfish: Biology and Exploitation"** by J. V. Huner and J. E. Barr has been published by the Louisiana Sea Grant College Program, Center for Wetland Resources, Baton Rouge, LA 70803-7507. From 30 to 60 million pounds of the red or red swamp crawfish, *Procambarus clarkii*, are harvested each year, mostly in Louisiana, though the species has been successfully introduced to both U.S. coasts, the West Indies, Central and South America, Europe, Africa, Hawaii, and Japan, and, perhaps, China.

General crawfish biology—external and internal anatomy and physiology—is reviewed, as is crawfish classification, zoogeography, and distribution of *P. clarkii*, as well as the species' ecological relationships. Also discussed are specific microbial and protozan diseases, internal and external parasites, and other conditions (i.e., uropod swellings, gas-bubble disease, soft-shell syndrome, hollow-tail snydrome, etc.).

Another section reviews production of wild and domestic red crawfish, their harvest, holding, live shipping and storage, processing and marketing, management (particularly in Louisiana's Atchafalaya basin), and population estimation. Finally, history and techniques of crawfish culture are described, including data on economics, pond types and construction, and water problems and management. Also included is information on feeds and fertilizers, pond crawfish population dynamics, rice/crawfish culture, and crawfish/fish polyculture, and more.

Three applications give data on other species of crawfish suitable for cultivation, a sample problem for calculating age classes and average sizes in a pond, and calculation of crawfish populations. Literature is not cited specifically in the text, but extensive references are listed by topic (general biology, diseases, taxonomy/zoogeography, ecology, etc.). The volume thus gives an in-depth look at the red swamp crawfish in a nontechnical, well-written book useful to students, aquaculturists, and others. The 136-page paperbound publication, LSU T-83-002, is available from the publisher at $10.00.

Fisheries Development in Third World Nations

Publication of **"Economics of Fisheries Development"** by Rowena Lawson has been announced by Praeger Publishers, 521 Fifth Avenue, New York, NY 10175. The author, Emeritus Reader in Development Economics, University of Hull, is currently a consultant in fisheries development, and her book reflects her emphasis and interest in fisheries development in the so-called developing nations, especially those with fairly new and large EEZ's.

The author begins with an overview and analysis of the state of world fisheries and the economic theory of fish resource exploitation. She then discusses marine fisheries management, fish marketing and processing and the economics of the fish market, planning for fisheries development, institutional arrangements for developing EEZ's, government initiated projects for fisheries development (feasibility studies and project formulation, analysis, appraisal, and evaluation), and development opportunities (small-scale fisheries, export-oriented fisheries, and aquaculture), with case studies drawn almost entirely from developing nations.

Appendices provide data on fishery organizations, CECAF terms, management term definitions, criteria for appraisal and review of fisheries projects, and a list of Canada's societal goals, policy objectives, and strategies for fishery management. Thus, the book constitutes an introductory text to the theoretical principles of fisheries economics and management and relates them to the fisheries of developing countries. Indexed, the 283-page hardbound volume is available from the publisher for $28.95.

Pacific Salmon Marketing

"Uncertainty, Market Disequilibrium, and the Firm's Decision Process: Applications to the Pacific Salmon Market," by Rebecca J. Lent, has been published by the Oregon State University Sea Grant College Program, AdS 418, Corvallis, OR 97331, as ORESU-T-84-002. The author has provided a model of the short-run decision-making behavior of buyers and sellers of Pacific salmon at the wholesale level to improve the understanding of this important salmon market and how it functions. She reviews pertinent literature on uncertainity and market disequilibrium, Pacific salmon production and markets, and concludes with recommendations for future research. The 109-page paperbound volume is available free from the publisher.

Editorial Guidelines for the *Marine Fisheries Review*

The *Marine Fisheries Review* publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, the *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Cited

Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, and the year, month, volume, and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8 × 10 inches, sharply focused glossies of strong contrast. Potential cover photos are welcome, but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 50 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

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